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PRECISION AGRICULTURE: BRIDGING TECHNOLOGY AND TRADITION VOLUME II

Editors:
Dr. Preetilagna Dhal
Dr. Ajit. K. Gedam
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PREFACE

Agriculture has always been the backbone of civilization, sustaining populations and shaping societies. From ancient practices of crop rotation to the Green Revolution, every era has brought innovations that have transformed the way we produce food. Today, we stand at the cusp of a new revolution—one driven by technology, data, and a deeper understanding of our environment.

"Precision Agriculture: Bridging Technology and Tradition" is a book that delves into this transformative era where age-old agricultural practices meet cutting-edge technology. The objective is not just to introduce new tools and methods, but to illustrate how these innovations can harmonize with traditional farming wisdom, creating a sustainable and efficient future for agriculture.

Precision agriculture, at its core, is about accuracy—using data to guide farming decisions, reduce waste, optimize resources, and increase yields. Yet, it is also about maintaining the delicate balance between innovation and the rich heritage of farming practices that have sustained humanity for millennia. This book seeks to bridge the gap between the digital and the practical, offering insights into how farmers, researchers, and technologists can collaborate to enhance food production while respecting the environment and preserving cultural traditions.

As you journey through these pages, you will explore the many facets of precision agriculture, from satellite imagery and GPS-guided equipment to soil sensors and machine learning algorithms. However, beyond the technology, this book also emphasizes the importance of human knowledge and experience—elements that are as critical to successful farming as any piece of hardware or software.

The chapters ahead bring together contributions from leading experts in the field, offering both theoretical insights and practical applications. Whether you are a farmer looking to modernize your practices, a student entering the world of agronomy, or a policymaker shaping the future of food production, this book aims to provide the knowledge and tools necessary to navigate the complexities of modern agriculture.

In an era where the global population is increasing, and environmental challenges are mounting, precision agriculture offers a beacon of hope. By marrying technology with tradition, we can ensure that agriculture remains not only productive but also resilient and sustainable for generations to come.

We invite you to explore the innovative world of precision agriculture, where tradition meets technology, and where the future of farming is being cultivated today.

Editors

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INTEGRATED DISEASE MANAGEMENT FOR WHEAT (*TRITICUM* SPP.)

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Introduction:

Wheat is one of the most important cereal crops grown all around the world. In India it is second most important food grain crop grown after rice. It is grown in almost all the northern states of India viz. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh and Bihar. In India it is sown in 339.20 lakh ha (agriwelfare.gov.in) which account for production of 112.74 million metric tons (pib.gov.in.). Wheat contains 9-10% protein and used widely for making chapatti, bread, semolina & pasta.

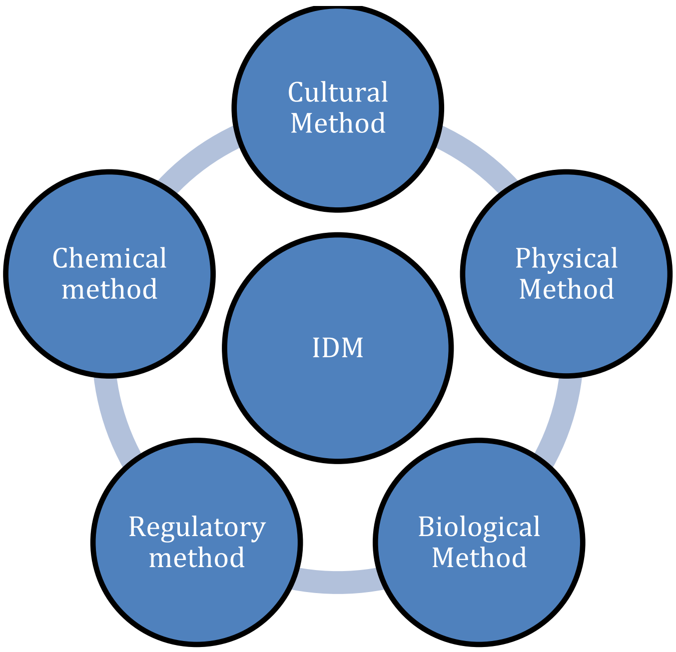
Wheat is staple food for more than half of the earth's population thus it plays a vital role in ensuring food safety. There are a lot of biotic and abiotic factors which hinder the production of wheat. Abiotic factors like increasing temperature, nutritional deficiency and rainfall at the time of harvest affects the production negatively. There are many biotic factors also which affect wheat viz. fungus, bacteria, virus & nematodes causing different diseases. Some of the most important diseases are mentioned in Table 1.

These disease causes around 30-40% loss of wheat yearly thus it is of prime importance to control them and mitigate economic losses. Traditionally chemical fungicides are used for controlling diseases caused by fungus which show higher efficacy and control the disease but on the other hand due to residual effect deteriorate the soil and wheat both. Due to bioaccumulation of these harmful pesticides in our food a lot of serious health problems arise which may be sometimes fatal to humans & livestock consuming them. So there is a need to adopt a holistic and comprehensive approach towards the management of disease.

Table 1: Important diseases and their causa, organism

Disease	Causal organism	References
Black/ stem rust	*Puccinia graminis tritici*	Pers, (1794)
Brown/ Orange/ Leaf rust	*Puccinia recondita*	Roberge ex Desm. (1857)
Yellow/ stripe rust	*Puccinia striformis*	Westend, (1854)
Loose smut	*Ustilago nuda tritici*	(C.N. Jensen) Rostr. (1889)
Flag smut	*Urocystis tritici*	Körn. (1877)
Hill bunt/ Common Bunt/ Stinking bunt	*Tilletia foetida*	J.G. Kühn, (1873)
Karnal bunt/Partial bunt	*Tilletia indica*	Mitra
Leaf Blight	*Alternaria triticina*	Prasada & Prabhu (1963)
Powdery mildew	*Blumeria graminis*	Speer (1975)
Yellow ear rot	*Clavibacter tritici*	(Carlson and Vidaver 1982) Zgurskaya *et al.* 1993
Tundu/Yellow slime	*Anguina tritici+ Clavibacter tritici*	(Steinbuch, 1799) Chitwood, 1935 (Carlson and Vidaver 1982) Zgurskaya *et al.* 1993
Ear cockle/ Seed gall	*Anguina tritici*	(Steinbuch, 1799) Chitwood, 1935

IDM stands for Integrated disease management. It combines all the available techniques in effective manner to keep the plant pathogen under economic threshold level so minimum losses incur in the production. Main components of IDM are-



- Cultural method- These involve various agronomic practices which help to manage the disease infestation. eg. early sowing, increase plant spacing, planting on raised bed etc.
- Physical method- physical manipulation of the environment thus pathogen doesn't get favorable condition to grow. eg. Soil solarization, soil sterilization, Hot water treatment etc.
- Biological control- Use of bioagents and antagonistic fungi against pathogen.eg. *Trichoderma harzianum, Trichoderma viridae, bacillus subtillis* etc.
- Regulatory method-These are quarantine methods which are adopted to stop the spread of a disease from a region of occurrence to the region where it is not found. eg. Flag smut of wheat which is introduced in India from Australia.
- Chemical method- Use of chemical fungicides, antibiotics and antisporulants for the control of plant disease. eg. Zineb, mancozeb, thiram, streptomycin etc.

IDM for wheat

Cultural control

- Collection and destruction of collateral and alternate host of wheat controls spread of rust fungi. eg. Berberis vulgaris, Briza minor, Bromus patula are alternate host for black stem rust, Thalictrum and Isopyrum fumaroides are alternate host for brown rust.
- Crop rotation should be adopted to avoid soil borne pathogens.
- Collection and burning of crop stubbles lower the incidence of disease like flag smut as many pathogens survive in the debris.
- Green manuring the field manages karnal bunt and other smut fungi.
- Use of certified and disease-free seeds for the control of seed borne pathogen.
- Early sowing of wheat decreases incidence of flag smut of wheat.
- Mixed cropping of wheat with non cereal crops like pea or mustard ensures economic yield despite complete destruction of wheat.
- Use of optimum dose of nitrogen as higher dose make plant succulent and thus susceptible to various pathogens while lower dose causes deficiency symptoms.
- Use of film forming antitranspirants like biofilm, Vapot Gard which hinders the penetration of germtube thus avoiding establishment of pathogen.

- Collection and destruction of infected wheat plants thus destroying the galls present in them.
- Use of wheat seeds free from nematode galls. Float wheat seeds in brine solution (20 kilograms of salt dissolved in 125 lit of water) for the detection of galls.
- Deep summer ploughing destroys the nematode galls by exposing them to extreme summer heat.
- Use of resistant variety like CPAN-1992, VL-401, HD-2204 for powdery mildew, HD-2888, DBW-17, HP-1014, NW-1067 for rust, PBW-65, HDR-70, VL-421, WL-410 for smut, IWP-87, HB-383, WL-410, Kalyan sona for common bunt, HD-1907, M-137A, HD-2222, UP-368, PBW 34, HD-30 for karnal bunt and VL-426, HD-2117, HW-121 for flag smut.

Deep Summer Ploughing

Seed Treatment-Brine Solution

Destruction of Alternate Host

Mechanical Control

- Hot water treatment (54-56^{o}C for 10-12 minutes) should be used for detection of *Anguina tritici* galls.
- Pre soaking of infected seed for 10-12 hrs followed by hot water treatment help to manage *Alternaria blight.*
- In 1892 hot water treatment was firstly used against loose smut. It could also be controlled by solar heat treatment where seeds are soaked in water for four hrs and then sun dried for 4 hrs in a bright sunny day.

Hot Water Treatment

Solar Heat Treatment

Biological control

- Spray of plant extract of *Reynoutria sachalinensis* develops resistance in wheat against *Blumeria*.
- *Verticillium lecanii, Paecilomyces fumosoroseus, Beauvaria bassiana & Metarrhizium anisopliae* show antagonistic effect against leaf rust and black rust fungi.
- *Trichoderma harzianum, Pseudomonas fluorescens* and *Gliocladium virens* is effective against smut of wheat.
- Common bunt of wheat may be managed by mycelium formulation of *Bacillus licheniformis, Bacillus megaterium* and *Pseudomonas fluorescens*.
- Seed treatment with skimmed milk, skimmed milk powder and wheat flour @ 160g per kg of seed or yellow mustard meal @60 g per kg seed effective manages common bunt.
- Use of hyper-parasite *Eudarluka filum* against rust.
- Seed treatment with conidial suspension of *Tricoderma harzianum* and *Trichoderma viridae* along with spray of leaf extract of *Azadirachta indica* (neem) & *Cassia fistula* (Amaltas) manages the karnal bunt very effectively.



Trichoderma harzianum ***Pseudomonas fluorescence*** ***Trichoderma viridae***

Chemical control

- For nematode control soil should be treated with aldicarb or carbofuron.
- Spay of karathane, Bayton (0.1-0.2%) or vigil (0.1-0.2%) provides 100% control of powdery mildew fungus.
- Foliar spray of Dithane M45@ 0.2% effectively manages rust fungi and Vitavax (carboxin), Tebuconazole (Raxilo)@ 1.25% & Bavistin (Carbendazim) @2.5-3g per kg seed gives 100% control of smut.
- Seed treatment with bayleton (0.1-0.2%) or carboxin 75 WP @ 1.5 g/kg seed before sowing effectively manages leaf blight.

- For internally seed borne disease like common bunt and flag smut of wheat seed treatment with Vitavax (0.2%) and Benlate (0.3%) is recommended.
- Spay of Tilt @ 250 or 500 ml/ha along with Tebuconazole or cyproconazole @ 500 or 200 ml/ha manages karnal bunt but not as effective as seed treatment with Agrosan GN or Thiram or Bavistin or Vitavax.

Seed Treatment with carboxin

Foliar spray of Tebuconazole

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NANOPESTICIDES: A PROMISING TOOL IN INSECT PEST MANAGEMENT

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Abstract:

Nanotechnology emerges as a promising alternative to conventional pest management, specifically addressing the drawbacks associated with chemical pesticides. Integrated pest management and traditional pesticides often lead to environmental harm, resistance issues and non-target organism toxicity. Nanotechnology offers benefits like heightened pest efficiency, reduced harm to non-targets and a sustainable approach to pest control. The controlled release of nanomaterials minimizes environmental impact, making it an appealing choice for eco-friendly agriculture. Ongoing research is crucial to refine nanotechnology's development, evaluation, and regulation, ensuring a more effective and environmentally conscious strategy for insect control.

Keywords: Nanotechnology, Nano-Pesticides, Formulation, Insect Pest Management

Introduction:

Nanopesticides, or nano plant protection products, represent a cutting-edge technological advancement with the potential to revolutionize pesticide use by offering various advantages, including heightened efficacy, increased durability and a reduction in required active ingredient amounts. Formulation options encompass nanoemulsions, nanocapsules employing polymers, and products featuring engineered nanoparticles like metals, metal oxides, and nanoclays. The term 'nano' originates from Greek, meaning dwarf, emphasizing the significant size reduction. The primary goal in developing nano-pesticides is to mitigate the environmental impact of pesticide active ingredients by enhancing their chemical efficiency, leveraging the benefits of extremely small particle sizes ranging from 1 to 100 nanometers. These nanoparticles enhance solubility, formulation stability, slow release of active ingredients, and mobility due to their smaller size and larger surface area. The anticipated improvement in the mode of action against target pests distinguishes nanoparticles from bulk materials. Additionally, nano-formulations offer systemic properties, uniform leaf coverage, and improved soil characteristics, making them valuable for sustainable agricultural practices and addressing the threats posed to non-target organisms and the environment by synthetic pesticides (Savary *et al.,* 2006).

Pesticides are indispensable in agriculture to increase crop yield. More than 90 percent of used insecticides are lost due to drift, leaching in the soil, degradation process (photolysis, hydrolysis). Only a small amount of pesticides reach the target site (1%), which requires repeated application of pesticides and has led to increased costs and pollution of the ecosystem. Farmers in the United States have spent $200 billion on pollination every year because the indiscriminate use of neonicotinoids has caused bee colony collapse disorder. In India, 28 percent of available pesticides are emulsifiable concentrates and oil-in-water emulsions, which are poorly soluble in water due to their non-polar nature. To increase their solubility, higher amounts of organic material such as xylene and surfactant are added. But organic solution/solvents are expensive, flammable and dermally toxic, and heavy metals present in surfactants accumulate in soil, creating abiotic stress in plants (Rice *et al.,* 2001).

Repeated use of certain pesticides, such as Malathion, has produced genotoxicity in humans. Almost 20,000 human deaths are counted each year due to the consumption of pesticides through food. Pesticides interact with the microbiome present in the human gastrointestinal tract and cause digestive problems, lung cancer and hormonal imbalance. Premature degradation of the *a.i* (active ingredient) in pesticide formulations by soil bacteria also reduces pesticide efficacy (Anderson *et al.,* 2016).

Nanotechnology stands on the brink of transforming various industries, encompassing agriculture, food, pharmaceuticals, aerospace, medicine, and construction. The expansive applications and benefits of nanotechnology extend to diverse fields such as electronics, cosmetics, coatings, packaging, biotechnology, materials science and more (Khatoon *et al.,* 2017). In agriculture, nanomaterials play a pivotal role, particularly in the development of nano-encapsulated conventional fertilizers, pesticides and herbicides.

These nano-formulations enable a controlled and gradual release of nutrients and agrochemicals, ensuring precise dosing to plants. Nanofertilizers, characterized by nanoparticle-sized nutrients or artificial metal oxide and carbon-based nanomaterials, along with nanopesticides, offer targeted release of agrochemicals, maximizing biological efficacy without the risk of overdosing. Additionally, nanomaterials contribute to environmental protection by facilitating the detection and removal of contaminants through innovative techniques like nanosensors and nanoremediation methods. The versatile applications of nanotechnology underscore its potential to revolutionize and enhance various aspects of modern industries (Lavicoli *et al.,* 2017).

The application of modern tools and techniques rooted in nanotechnology holds the potential to address various challenges associated with conventional insect pest management, presenting a potential revolution in the field (Duhan *et al.,* 2017). The encouraging outcomes have paved the way for significant advancements in insect pest control. Nanoparticles emerge as promising agents for managing and controlling insect pests. These applications encompass safeguarding against pests through nanomaterial-based formulations of pesticides and insecticides, utilizing nanoparticles for gene or DNA transfer into plants to develop insect-resistant varieties, and enhancing agricultural productivity via slow nutrient release using nanoparticle encapsulation. Traditional agricultural approaches, such as integrated pest management and the use of synthetic pesticides like dichlorodiphenyltrichloroethane (DDT), fenthion, and malathion, exhibit adverse effects on both animals and humans, contributing to soil fertility decline. To surmount these challenges, active research has been directed toward developing new pesticides rooted in nanotechnology, commonly referred to as "Nanopesticides."

Need of nano-formulation:

- Meet the demands of efficacy
- Increase water solubility
- Suitability to the mode of application
- Minimizing the damage to the environment

Formulations of nano-pesticides

The development of nano-pesticides involves various formulations designed for crop protection, including nanoinsecticides, nanoherbicides, nanofungicides, and nanonematicides. These formulations aim to enhance solubility, ensure slow release of active ingredients, and prevent degradation. Diverse modifications in the chemical carrier molecule have led to classifications such as organic polymers, lipids, nanoparticles, metals and metal oxides, and clay-based nanomaterials. Notable nanoformulations include (Dimetry and Hussein, 2016):

Nano-emulsions: These are oil-in-water emulsions where the active chemical is dispersed as nanoparticles in water. They can be thermodynamically stable or kinetically stable, with examples like neem oil nanoemulsions developed for insect control.

Nano-suspensions: Also known as nanodispersions, these involve dispersing solid pesticide nanoparticles in an aqueous medium. Examples include aqueous dispersions of nano-permethin, Novaluran, and β-cypermethrin.

Nanogel: Hydrogel nanoparticles are also known. These are formulated by cross-linking polymer particles with hydrophilic groups so they absorb more water, e.g; Chitosan nanogel.

Nano-fibres: Nanofibers are developed using electrospinning, a thermally induced phase separation. Researchers have developed electrospun nanofibers loaded with the chemical, (Z)-9-dodecenyl acetate, a pheromone component that embeds itself into a polymer matrix to control many insect pests of the order Lepidoptera.

Polymer-based nano-particles: Mainly used for slow and controlled release, these carriers improve dispersion in aqueous media. Examples include nanoencapsulation, nanospheres (e.g., bifenthrin nanoparticles), nanogels (e.g., chitosan nanogel), and nanofibers developed through electrospinning.

Nano Encapsulation: This involves packaging an active ingredient on a nanoscale into a protective shell. For instance, controlled-release nanoformulations of neonicotinoid insecticides like acetamipirid and imidacloprid have been developed.

These diverse nanoformulations showcase the versatility of nanotechnology in addressing challenges in insect pest management, offering improved efficacy and targeted delivery for more sustainable agricultural practices.

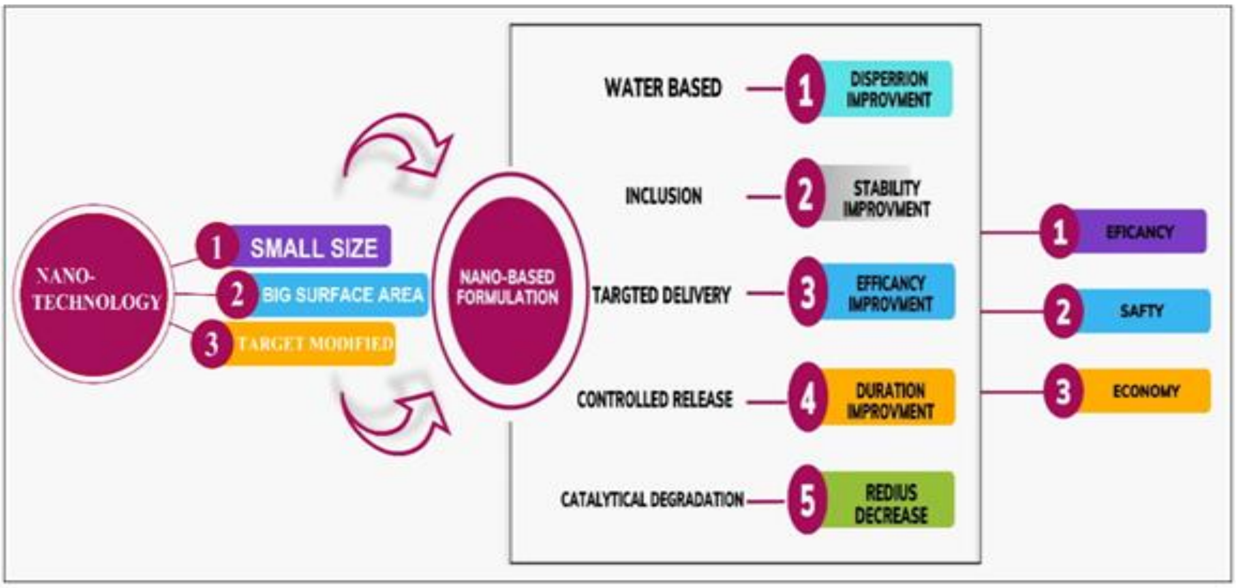

Figure 1: Beneficial enhancements of nano-pesticide formulations (Urkude, 2019)

Nanotechnology applications in agriculture:

- **Precision pest management:** Nanomaterials enable the development of precise, effective, and safer pesticides, herbicides, and fertilizers, allowing controlled release (Kuzma and VerHage, 2006).
- **Molecular biology tools:** Nanotechnology introduces new instruments for molecular biology, aiding in the identification of plant disease microorganisms
- **Revolutionizing disease detection:** Nanotechnology offers tools for disease detection, targeted treatment, and enhances plants' ability to resist pests and withstand environmental pressures.
- **Postharvest product management:** Nanotechnology addresses challenges in managing postharvest products, contributing to improved quality through rational selection and processing of raw materials (Rickmann *et al.,* 2003).
- **Productivity enhancements:** Applications include non-porous zeolites for efficient water and fertilizer dosing, nanocapsules for precise herbicide delivery, and nanosensors for pest detection.
- **Smart sensors and transport systems:** Nanotechnology aids in the development of intelligent sensors and transport systems to combat infections and other crop pathogens, enhancing overall crop health.
- **Environmental sustainability:** Nanotechnology contributes to environmental sustainability by offering renewable energy sources and strategies for pollution reduction and cleanup.
- **Reduced chemical usage:** Nanomaterials in agriculture reduce chemical spray usage through smart delivery systems, minimizing nutrient loss during treatments and increasing yields.
- **Advancements in genetic modification:** Nanotechnology is explored for its potential contributions to plant breeding and genetic modification (Tomey *et al.,* 2007).
- **Bio-nanocomposites:** Agriculture holds promise for bio-nanocomposites with improved physico-mechanical properties, utilizing materials like wheat straw and soybeans for bio-industrial purposes (Alamdar and Sain, 2008).

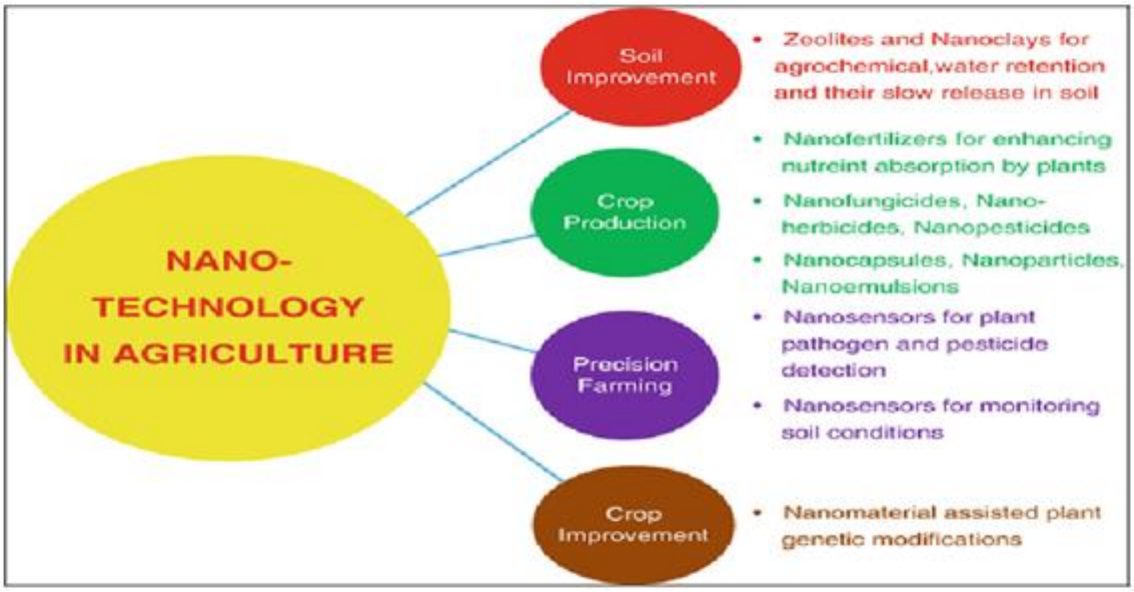

Figure 2: Nanotechnology in agriculture (Kaushal and Wani, 2017)

NPs in plant protections

Plant protection against insects and pests has benefited from nanotechnology. The nanoparticles could be useful in the formulating new pesticides, insecticides, and insect repellent compositions. The broad application of nanotechnology in the agri-sector as nanofungicides, nanoherbicides, nanoinsecticides, nanofertilizers, nanomicronutrients, nanobiopesticides, and nanobiosensors.

Nanoinsecticides

The potential use of nanoparticle in pest management has been successfully documented (Bhattacharyya *et al.* 2010). In the control of polyphagous pest, Helicoverpa armigera, notable application of nanoparticles has been reported (Vinutha *et al.* 2013). Synthesized Ag NPs reveal excellent mosquito larvicidal and antilice activity (Jayaseelan *et al.* 2011). Nanoencapsulation helps to promote the gradual release of chemical compounds for a distinct host for the management of insect by releasing some of the activities such as diffusion, biodegradation and osmotic pressure (Vidyalakshmi *et al.* 2009). The acceptable application of amorphous nanosilica as a pesticide has been found in several agricultural findings (Barik *et al.* 2008). Nanocopper is a modified nanoparticle which is suspended in water and used in a known compound, Bouisol, as fungicide for some grape varieties and other fruit crops. Because of mutagenesis, viral capsids could be changed to achieve several elements like the production of some enzymes and nucleic acids to act against parasites (Perez-de-Luque and Rubiales 2009). Nanoparticles with silver at 100 mg/kg restrain growth of mycelium and germination of conidia on cucurbits and inhibit the growth rate of powdery mildew in pumpkins (Lamsal *et al.* 2011). As one of the elite nanopesticides, silver nanoparticles show a significant application in agriculture practices (Afrasiabi *et al.* 2012). Treatment of mulberry leaves affected by grasserie disease is done by application of the ethanolic suspension of hydrophobic alumina-silicate nanoparticles, which has remarkably minimized the viral load (Goswami *et al.* 2010). DNA-tagged Au NPs are powerful for *Spodoptera litura* and hence they taken as a functional element for integrated pest management (Chakravarthy *et al.* 2012).

Table 1: Nanopesticides and their effect on target organisms (Parvez *et al.*, 2019)

Nanoparticles	Active ingredient	Target organism
Nanoencapsulation	EO *Carum copticum* (L.)	*Plutella xylostella*
Myristic acid-chitosan nanogels	„	*Sitophilus granarius Tribolium confusum*
PEG NPs	EO of geranium and bergamot	*Blatella germanica*
PEG NPs	EO of garlic	Tribolium castaneum
SiO2 NPs	pinene and linalool	*Spodoptera litura Achaea janata*
NPs	amorphous permethrin	*Culex quinquefasciatus*
NPs	microparticular permethrin	*Aedes aegypti*
chitosan-coated	alpha-cypermethrin	Controlled release
NPs	*Azadirachta indica*	*P. xylostella*
Nanogel	methyl eugenol	*Bactrocera dorsalis*
ABA triblock copolymer	Imidacloprid NPs	Increased efficacy
ABA type copolymer with TiO2 NPs	Indoxacarb NPs	Increased efficacy
Natural chitosan and sodium alginate	imidacloprid	self-assembly the release
Nanocapsules	Pyridalyl	Specific release *Helicoverpa armigera*
Nanocapsules with azidobenzaldehyde	Methomyl	Armyworm
PEGs-amphiphilic copolymers	thiamethoxam, thiram, carbofuran, β-cyfluthrin	Controlled release
Core-shell polymeric PEG nano micelles	diethylphenyl acetamide (DEPA)- 154nm	Insect repellent *Culex tritaeniorhynchus*
Chitosan-coated nanoformulations	Pyrifluquinazon	*Myzus persicae*
chitosan nanocarrier	*Nomuraea riley*	S. *litura*
Nano dust	nano-Al2O3 dust	*Sitophilus oryzae* and *Rhyzopertha dominica*
NPs	CoNPs of 84.81 nm	*A. subpictus, A. aegypti*
	TiO2 NPs	*Bombyx mori*
	TiO2 NPs and AgNPs	*Hippobosca maculate, Bovicola ovis*
	ZnO NPs	cattle tick, the head louse, larvae of malaria vector and filariasis vector

The mode of action/entry of nanoparticles in insect:

Nanoparticles penetrate insects through physical contact, ingestion and inhalation. Upon physical contact, the nanoparticles penetrate the exoskeleton; bind the nanomaterials to sulfur from protein or phosphorus from DNA in the intracellular space, leading to organelle and enzyme denaturation, leading to cellular fraction and cell death (Abd-Elsalam *et al.*, 2018). Dust nanoparticles are commonly used to control stored grain pests and the mechanism relies on physical disruption. The nanoparticles dehydrate the insect's body by attaching to their waxy cuticle layer. Nanoclay, nanoalumina, and nanosilica are attached to the insect's cuticle and absorb water from the insect's body. The hydrophobic behavior of nanosilver particles causes cracks and scratches on the insect body, changes membrane properties, resulting in changes in cell permeability and respiration, damages DNA and releases toxic Ag+ ions. Ag nanoparticles interfere with melanin synthesis. Inhalation of nanoparticles leads to internalization in cells via phagocytosis, which causes deterioration of the midgut and alters the activity of metabolic genes and decreases lipid, protein and glucose levels. Inhalation also changed the activity of nervous system enzymes and membrane potential e.g. Zn NPS and Tio2 NPS bind to acetylcholine esterase and β carboxyl esterase and affect their activity. The mode of action of these nanoparticles is same as that of organphosphorus and carbamate insecticides. Ag nanoparticles affect the enzyme Glutathione S transferase. In *Spodoptera litura*, Ag nanoparticles act as an amylase inhibitor. The reactive oxygen species is considered as the most cellular effects induced by nanoparticles and the excessive generation of free radicals induces DNA damage through inflammatory processes.

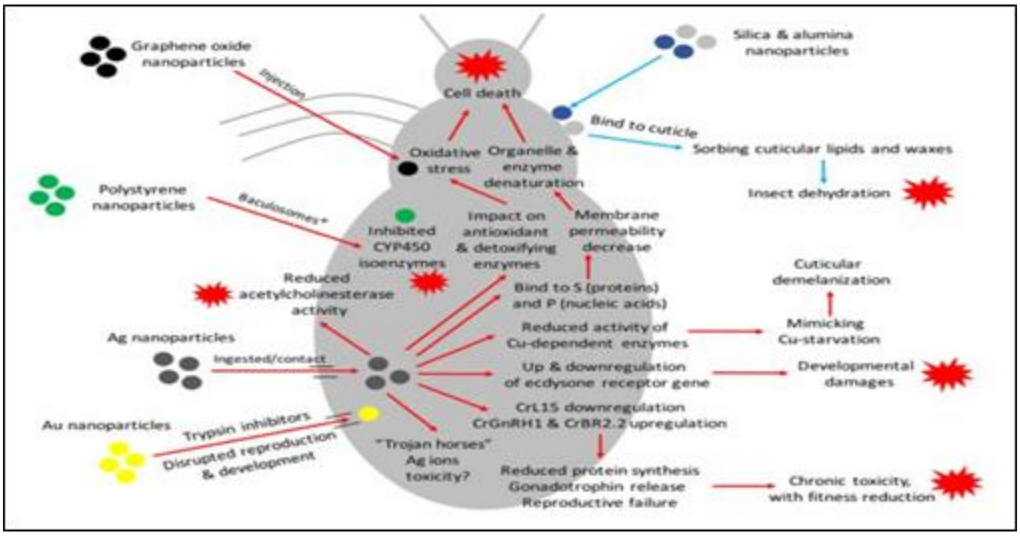

Figure 3: Mode of entry of nanopesticides/nanoparticles in insect (Rafiq *et al.,* 2022)

Synthesis of nanomaterial

Synthesis of nanomaterials is to produce a material that consists properties of nanometer range (1-100 nm). The synthesis methods are appropriate that controls the size in this range so that one feature or another can be achieved. The methods are two types: bottom-up and top-down (Parvez *et al.,* 2019).

1. **Top-down method:** Involves breaking down solid materials into small pieces through the application of external force. Utilizes various physical, chemical, and thermal techniques to provide the necessary energy for nanoparticle formation.
2. **Bottom-up approach:** Involves gathering and combining gas or liquid atoms or molecules to create nanoparticles. This approach contrasts with the top-down method and has its own set of advantages and disadvantages.

Methods of nanoparticle synthesis

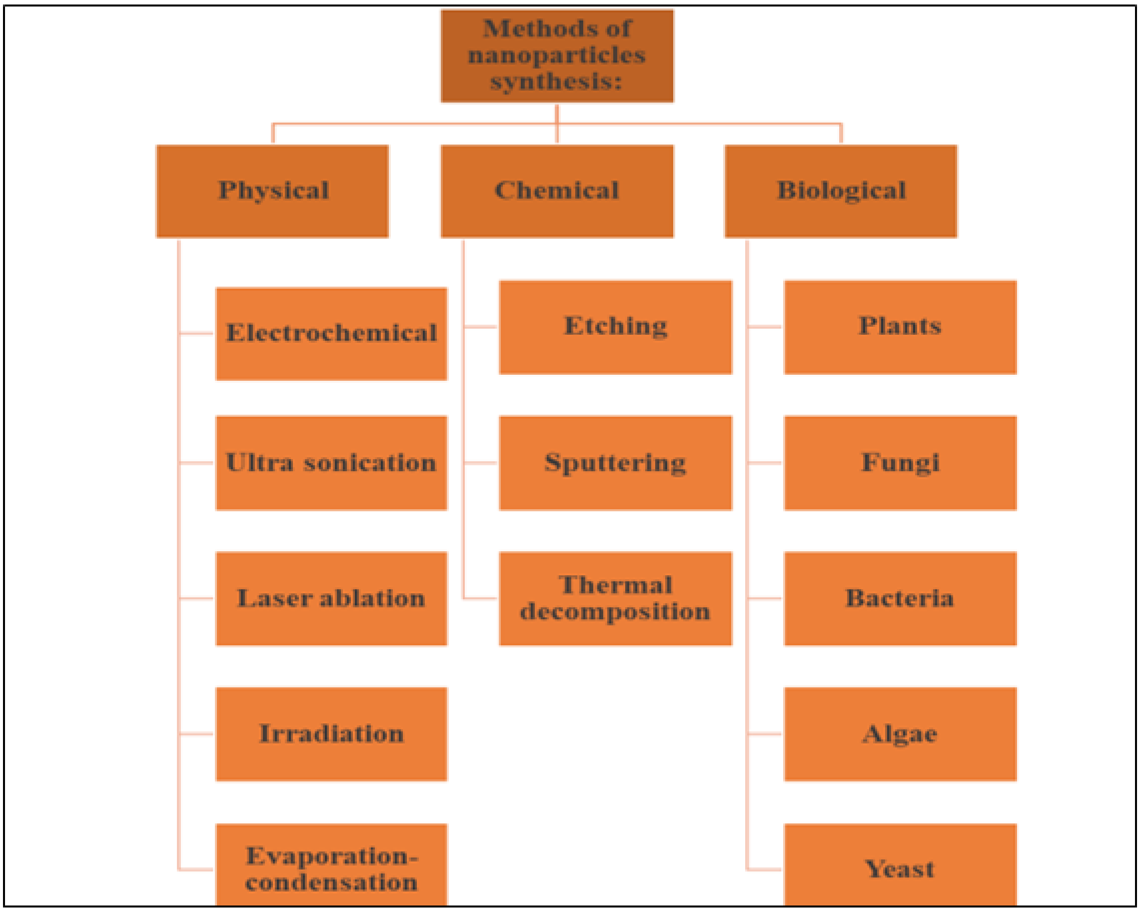

Figure 4: Methods of nanoparticle synthesis (Parvez *et al.,* 2019)

Green synthesis of nanoparticles

Green synthesis serves as a crucial tool to mitigate the negative impacts associated with traditional nanoparticle synthesis methods commonly used in both laboratory and industrial settings. This approach employs natural extracts, derived from diverse sources, to facilitate the synthesis of metal and metal oxide nanoparticles, including gold, silver, copper oxide, and zinc oxide. Key biological components, such as essential phytochemicals (e.g., flavonoids, alkaloids, terpenoids, amides, and aldehydes), play a dual role as reducing agents and contributors to solvent systems (Singh *et al.,* 2018).

The adoption of green synthesis principles in material and nanomaterial production directly enhances environmental friendliness. This includes the regulation, control, clean-up, and remediation processes, which collectively contribute to the sustainability of nanoparticle production. The fundamental tenets of green synthesis emphasize waste prevention or minimization, reduction of derivatives and pollution, utilization of safer and non-toxic solvents and auxiliaries, as well as the incorporation of renewable feedstock. By adhering to these principles, green synthesis not only ensures eco-friendly material creation but also aligns with sustainable practices, reducing the ecological footprint associated with conventional synthesis methods and promoting a more environmentally conscious approach to nanomaterial production (Nadaroğlu *et al.,* 2017).

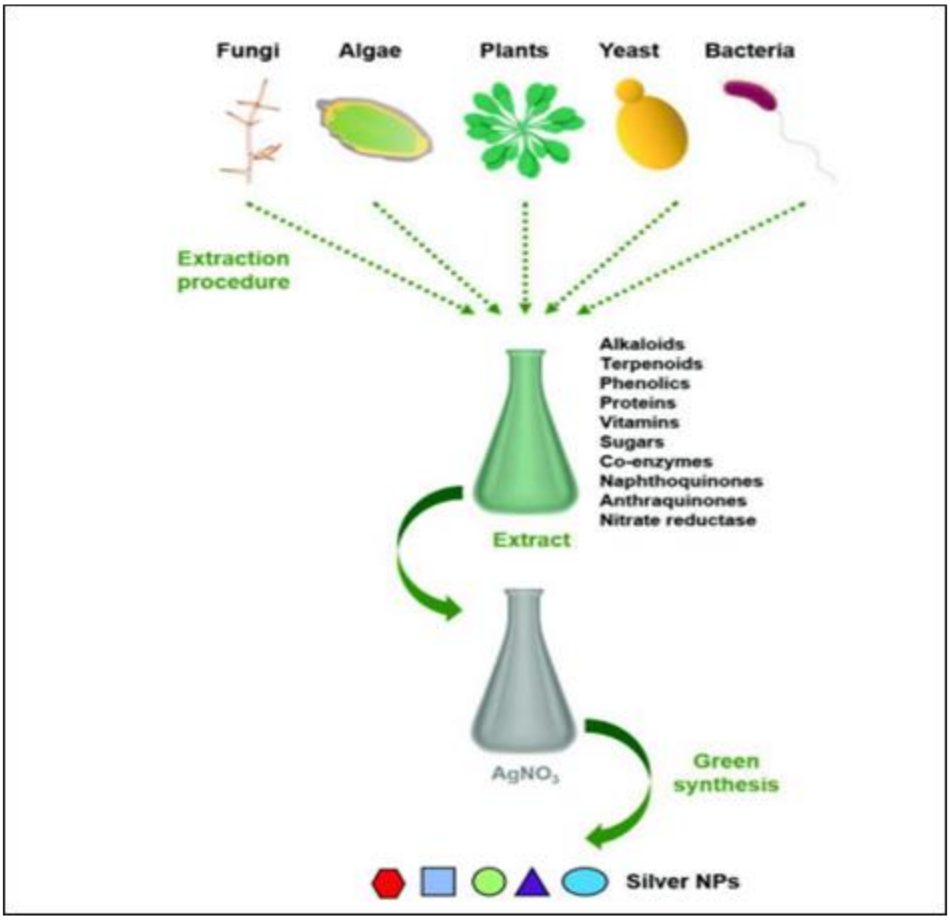

Figure 5: Diagrammatic representation of the green synthesis of AgNPs (Roy *et al.,* 2019)

The major advantages of use of nano-pesticides over conventional pesticides are:

- **Target specificity:** Nanotechnology enables the development of highly target-specific nano-pesticide formulations.
- **Controlled release:** Nano-pesticides facilitate targeted delivery and controlled release mechanisms, improving pesticide utilization and minimizing residues and pollution.
- **Nano-microcapsule formulations:** Utilizing light-sensitive, thermo-sensitive, humidity-sensitive, enzyme-sensitive, and soil ph-sensitive high polymer materials, nano-microcapsule formulations ensure slow release and protection of pesticides.

- I**mproved adhesion:** Nano-pesticide formulations enhance droplet adhesion on plant surfaces, reducing drift losses and improving the dispersion and bio-activity of pesticide molecules.
- **Efficacy over conventional formulations:** Nano-pesticides demonstrate higher efficacy compared to conventional formulations (d-dust, g-granule, p-pellet, etc.) Due to their small size, improved droplet ductility, wettability, and target adsorption during field application.
- **Increased apparent solubility:** Nano-pesticides increase the apparent solubility of poorly soluble active ingredients, protecting them against environmental degradation and ensuring slow/targeted release.
- **Reduction in environmental contamination:** Nano-pesticides contribute to reduced environmental contamination by minimizing the reuse of conventional pesticides and reducing losses.
- **Cost and safety benefits:** The use of nanopesticides reduces costs, human mucosal irritation, phytotoxicity, and damage to non-target organisms, providing safer and more environmentally friendly alternatives.
- **Increased delivery system efficacy:** Nano-pesticide delivery systems exhibit increased efficacy and higher toxicity, resulting in a reduced amount of pesticide used, thereby lowering pollution loads and input costs.
- **Safety from an environmental perspective:** Nano-pesticides offer safer alternatives from an environmental standpoint, aligning with sustainable and eco-friendly practices.

Disadvantages of use of nano-pesticides

- **Contamination risks:** Nano-pesticides may introduce new soil and water contamination issues due to their prolonged persistence, increased transport, and higher toxicity. Some nanoparticles, such as silver nanoparticles (agnps), pose risks by exhibiting higher toxic effects than their conventional counterparts, with the ability to penetrate biological barriers like cell membranes.
- **Specific risks of nanoparticles:** Silver nanoparticles (agnps) contribute to increased toxicity compared to silver nitrate and can cause liver toxicity (bile duct hyperplasia) upon inhalation and oral ingestion. Alumina nanoparticles impede root growth in various plant species, including cucumber, cabbage, carrot, corn, and soybean.

- **Phytotoxicity concerns**: Nano-pesticides have the potential to be phytotoxic, impacting plants, animals, and the environment, depending on the type of nanomaterial used. Adverse effects on root elongation and seed germination percentage are observed at different growth stages, particularly with higher concentrations and specific types of nanomaterials.
- **Nanosilver toxicity:** Approximately 100 pesticides containing silver (ag) are used for antimicrobial properties, but the main concern lies in the toxicity of nanosilver to ecosystems and humans.
- **Challenges and considerations for future research:** Unpredictability in plant responses: the response of nanomaterials in different plants can be unpredictable, necessitating further investigation.
- **Phytotoxicity at higher concentrations:** Higher concentrations of nanomaterials may lead to phytotoxic effects.
- **Reduced plant uptake and photosynthesis:** Larger nanomaterials may hinder plant uptake and photosynthesis, requiring attention in future research on nanomaterials for plant germination and growth.

Conclusions and future perspectives:

Nanotechnology is rapidly becoming a game-changer in agriculture, with a focus on elevating crop production and ensuring environmental sustainability, particularly in the realm of soil protection. Among the various technologies emerging in this field, nanobiotechnology stands out for its potential to deliver environmentally efficient outcomes across energy production, consumer goods, agricultural crops, and information technologies. This burgeoning innovation not only holds promise for addressing pressing environmental concerns but also provides adaptive solutions to cope with changing environmental conditions, such as those arising from the impact of climate change.

Ongoing research endeavors in agricultural nanotechnology are geared towards finding effective solutions to prevalent environmental and agricultural challenges. Nanomaterials, distinguished by their minute size and unique physical, chemical, and biological properties, are regarded as compelling and safe tools for revolutionizing agricultural practices. These nanomaterials demonstrate remarkable efficacy in diverse agricultural applications, serving as intelligent delivery systems for nutrients, indicators of soil and plant health, and chelators capable of removing toxic substances from the soil. Despite their substantial potential, the transition of nanomaterial-based products to the market faces hurdles like significant initial investments, regulatory complexities, and public apprehensions concerning their nanoscale characteristics and potential biological risks. Addressing these challenges is paramount for ensuring the continued development and widespread adoption of nanotechnology in agriculture.

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PRECISION AGRICULTURE - TOOLS, SENSORS FOR INFORMATION ACQUISITION AND FERTIGATION

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Abstract:

The integration of Internet of Things (IoT) technology in agriculture promises a shift from manual and static practices to dynamic and intelligent systems, revolutionizing productivity with minimal human intervention. Central to this transformation are Precision Agriculture (PA) and Wireless Sensor Networks (WSN), driving automation in the agricultural sector. PA employs specialized sensors and software to precisely manage crop needs, optimizing both productivity and sustainability by collecting real-time data on soil conditions, crop health, and weather via deployed field sensors. Additionally, high-resolution imagery from satellites or drones is processed to derive actionable insights for informed decision-making.

This paper reviews the landscape of near and remote sensor networks within agriculture, addressing key considerations and challenges. It encompasses wireless communication technologies, sensor applications, and environmental monitoring capabilities, along with platforms for capturing spectral images of crops and utilizing common vegetation indices for spectral analysis. The survey also explores practical applications of WSN in agriculture, culminating in a case study demonstrating the implementation of a WSN-based PA system.

Furthermore, we propose an IoT-based solution for intelligent crop health monitoring, featuring two modules. The first module deploys a WSN for real-time monitoring of crop health status, while the second module utilizes low-altitude remote sensing to capture multi-spectral imagery for classifying healthy and unhealthy crops. Our findings highlight the efficacy of this approach through empirical results from the case study, while identifying challenges and future directions for research and implementation.

Keywords: Internet of Things (Iot), Precision Agriculture (PA), Wireless Sensor Networks (WSN), Agriculture Automation, Crop Health Monitoring, Spectral Imaging, Environmental Monitoring

Introduction:

In today's world, where the human population is constantly rising the primary concerns are access to clean water, breathable air, and sufficient food to meet growing demand. Climate change is causing unpredictable shifts in agricultural productivity, raising significant worries about food security. As arable land continues to decrease, the pressure on remaining agricultural land is intensifying. The per capita land area, which was 0.23 hectares in 2000, is projected to shrink to 0.15 hectares by 2050. In response, researchers are working to ensure both food and nutritional security while also focusing on environmental sustainability.

To address these challenges, accurate prediction models are essential for providing reliable data and insights. Enhancements in crop yield can be achieved through improved field management, reduced chemical and fertilizer use, and more efficient applications of information technology. These advancements can lead to better farm records, increased profit margins, and reduced pollution. Key technologies being integrated include Global Positioning System (GPS), Geographical Information System (GIS), real-time and remote sensors, telecommunication, mobile computing, and advanced information processing models. These innovations aim to optimize agricultural practices and support sustainable food production

During irrigation, the liquid fertilizer solution is continuously and repeatedly supplied into the system at low rates. The injector's flow rate should maintain a constant supply of solution throughout the irrigation cycle, starting fertigation immediately and ending a few minutes before the system's end.

Regarding the selection of fertilizers, we should take into account factors like solubility, acidity, quantity, and cost, in addition to the amount and type.

What is precision farming or precision agriculture?

Precision agriculture relies heavily on advanced tools and sensors for acquiring precise information about various aspects of farming operations. These tools and sensors play a crucial role in optimizing agricultural practices such as planting, irrigation, fertilization, and pest management. Here are some key tools and sensors commonly used in precision cultivation: Soil Sensors, Weather Stations, Remote Sensing, Nutrient Management Tools, Pest and Disease Monitoring, Crop Monitoring and Yield Mapping, Data Management and Decision Support Systems

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Therefore, it is also considered as the future of agriculture. Scientifically, precision agriculture is a decision-making agricultural system that uses observed information and is intended to improve the agricultural process through precise management of each step to ensure maximum agricultural production and continued sustainability of the natural resources, because it can provide timely and accurate information to the producer to make suitable management decisions.

Precision agriculture works in a converged approach with resource application, soil properties, agronomic practices, crop requirements, plant protection as they vary across a site, precision land managements are made easy and such data can be acquired through map-based approach or sensor-based information.

At the same time, the producer must understand that Precision farming cannot solely be characterized as use of high-tech equipment, but the acquisition and wise use of obtained information from that technology is vital for getting most out of a piece of land.

Soil Sensors:

Soil moisture sensors: Measure the water content in the soil, helping farmers to determine the optimal irrigation schedule and amount.

Types of soil moisture sensors:

Time Domain Reflectometry (TDR): Measures soil moisture by sending electromagnetic pulses through the soil and measuring the time taken for reflections. This method is accurate but often more expensive.

The sensor measures the time it takes for the electromagnetic pulse to travel down the probe, reflect off the boundary where soil moisture changes, and return to the sensor. This time delay is directly related to the soil moisture content.

Frequency Domain Reflectometry (FDR): Uses the frequency of electromagnetic waves to determine soil moisture content. It is also accurate and more cost-effective compared to TDR.

The sensor uses the frequency of the electromagnetic wave and the amplitude of the reflected signal to estimate soil moisture content. Changes in the soil's dielectric constant, influenced by moisture content, alter the wave's frequency and amplitude characteristics.

Gravimetric soil moisture sensors:

These sensors measure soil moisture by comparing the weight of soil samples before and after drying. They provide accurate readings but are typically used in research settings rather than field applications due to the labor-intensive nature of sample collection.

Capacitance soil moisture sensors:

These sensors measure soil moisture based on the dielectric constant of the soil, which changes with moisture content. They are commonly used in agricultural applications due to their accuracy, ease of installation, and relatively lower cost compared to other methods.

How soil moisture sensors work:

Soil moisture sensors typically consist of a probe or a set of probes that are inserted into the soil at various depths.

Capacitance sensors measure the dielectric permittivity of the soil, which changes as the soil moisture content changes. This change is then converted into a moisture reading.

TDR sensors measure the time it takes for an electromagnetic pulse to travel through the soil and reflect back. This time is directly related to the soil's moisture content.

FDR sensors use the frequency of electromagnetic waves and the dielectric properties of the soil to estimate soil moisture.

Applications of soil moisture sensors:

Optimizing irrigation: By monitoring soil moisture levels in real-time, farmers can apply water precisely when and where it is needed, reducing water usage and minimizing runoff.

Monitoring crop health: Soil moisture affects nutrient availability and root health. Monitoring soil moisture helps farmers ensure optimal conditions for plant growth and prevent stress due to under or over watering.

Improving yield and quality: Proper soil moisture management contributes to better crop yield and quality, as plants can access nutrients more efficiently and are less susceptible to diseases associated with water stress.

Environmental sustainability: Efficient irrigation practices based on soil moisture data help conserve water resources and minimize the environmental impact of agriculture.

In summary, soil moisture sensors are invaluable tools in precision agriculture, providing essential data that supports informed decision-making and helps farmers optimize irrigation practices, improve crop health, and enhance overall agricultural productivity and sustainability.

Soil temperature sensors: Monitor soil temperature, which affects seed germination, nutrient availability, and microbial activity.

It's a crucial device used in agriculture to monitor and manage soil temperature variations. They play a vital role in optimizing planting times, managing crop growth, and improving overall agricultural productivity. Here's an overview of soil temperature sensors, their types, working principles, and applications:

Types of soil temperature sensors:

Thermistor sensors:

Thermistors are semiconductor devices whose electrical resistance changes with temperature. Soil temperature sensors based on thermistors measure this change in resistance to determine soil temperature. They are widely utilized for their accuracy, reliability, and relatively low cost. Thermistors can be buried at various depths in the soil to monitor temperature profiles.

Thermocouple sensors:

Thermocouples consist of two dissimilar metal wires welded together at one end. The temperature difference between the welded junction and the free ends generates a small voltage, which is proportional to the temperature difference. They are robust and can measure a wide range of temperatures. However, they are less accurate than RTDs and thermistors.

Working principle of soil temperature sensors:

Installation: Soil temperature sensors are typically installed at various depths within the soil profile, depending on the specific agricultural application and the crop being monitored.

Temperature measurement: The sensor detects changes in temperature through its sensing element (thermistor, RTD, or thermocouple).

Electrical signal output: As the soil temperature changes, the sensor converts this temperature change into an electrical signal (resistance change for thermistors and RTDs, voltage change for thermocouples).

Signal processing: The electrical signal is then processed and converted into a temperature reading using calibration curves or algorithms specific to the sensor type.

Data interpretation: The soil temperature data collected by these sensors is crucial for determining optimal planting times, assessing soil health, and managing irrigation and nutrient applications.

Applications of soil temperature sensors:

Planting decisions: Farmers use soil temperature data to determine the best times for planting crops. Different crops have specific temperature requirements for germination and growth.

Frost protection: Monitoring soil temperature helps farmers predict and prevent frost damage by taking timely protective measures.

Crop management: Soil temperature influences nutrient availability, root growth, and overall crop health. Monitoring soil temperature helps optimize nutrient application and irrigation schedules.

Research and monitoring: Soil temperature sensors are also used in research studies to understand soil dynamics, climate change impacts, and ecosystem processes.

In summary, soil temperature sensors are essential tools in agriculture for monitoring soil temperature variations accurately and efficiently. They contribute to improved crop management practices, better resource utilization, and enhanced agricultural productivity.

Weather stations: Weather stations are comprehensive systems designed to measure various meteorological parameters and environmental conditions. They play a critical role in agriculture by providing real-time data that farmers use to make informed decisions about planting, irrigation, fertilization, pest management, and overall farm management. Here's an overview of weather stations, their components, working principles, and applications in agriculture:

Meteorological sensors: Measure parameters such as temperature, humidity, wind speed, and rainfall. This data is crucial for predicting weather patterns and making informed decisions about planting and spraying schedules.

Components of a weather station:

Humidity sensor: Measures relative humidity, which indicates how much moisture is in the air. High humidity levels can affect disease pressure and crop drying conditions.

Wind sensors: Anemometers measure wind speed, crucial for determining potential evapotranspiration rates and assessing wind damage risk. Wind vanes measure wind direction, important for pesticide application, ventilation in greenhouses, and understanding microclimates.

Rain gauge: Measures precipitation levels, including rainfall and snowfall. Precipitation data helps in scheduling irrigation, predicting soil erosion, and managing drainage systems.

Barometric pressure sensor: Measures atmospheric pressure, which affects weather patterns, plant growth, and animal behavior.

Solar radiation sensor: Measures solar radiation levels, essential for understanding energy availability for crop photosynthesis and calculating potential evapotranspiration rates.

Data logger and communication interface:

Weather stations are equipped with data loggers to collect and store sensor data. They also include communication interfaces (such as Wi-Fi, cellular, or Ethernet) to transmit data to central databases or cloud platforms for remote access and analysis.

Working principle of weather stations:

- **Data collection:** Each sensor within the weather station continuously measures its respective parameter (temperature, humidity, wind speed, etc.).
- **Data integration:** The data from all sensors are collected and processed by the data logger, which timestamps and organizes the data into readable formats.
- **Data transmission:** Weather stations transmit the processed data to a central database or cloud platform via wired or wireless communication methods.
- **Data analysis and presentation:** Farmers and agricultural professionals access the weather data through user-friendly interfaces (like apps or web portals), where they can analyze trends, generate reports, and make decisions based on current and historical weather conditions.

Applications of weather stations in agriculture:

- **Irrigation management:** Real-time weather data helps optimize irrigation schedules based on current soil moisture levels, precipitation forecasts, and evapotranspiration rates.
- **Frost protection:** Monitoring temperature trends and receiving frost alerts allows farmers to take preventive measures, such as applying frost protection techniques.
- **Pest and disease management:** Weather stations provide data on temperature, humidity, and rainfall patterns that influence pest and disease outbreaks. Farmers can implement timely interventions based on weather forecasts and historical data.
- **Crop planning and management:** Understanding weather conditions aids in crop selection, planting schedules, and adjusting agronomic practices based on seasonal variations.

In conclusion, weather stations are indispensable tools in modern agriculture, offering precise and timely meteorological data that farmers use to enhance productivity, sustainability, and profitability while minimizing risks associated with weather variability.

Remote sensing:

Satellite imagery: Provides high-resolution images of fields, which can be used to monitor crop health, detect stress, and assess overall vegetation vigor. Satellite imagery refers to photographs or digital images of Earth's surface captured by satellites orbiting the planet. These images are used for various purposes, including environmental monitoring, land use planning, agriculture, disaster management, and scientific research. Here are key points about satellite imagery:

Technology: Satellites equipped with sensors capture images in different wavelengths of light, ranging from visible to infrared and microwave.

Applications:

Environmental monitoring: Tracking changes in land cover, deforestation, urban growth, and monitoring natural disasters like wildfires and floods.

Agriculture: Assessing crop health, monitoring vegetation growth, predicting yields, and optimizing irrigation and fertilizer application.

Urban planning: Mapping urban sprawl, infrastructure development, and assessing population density.

Disaster response: Providing rapid assessment and mapping of disaster-affected areas for relief operations.

Scientific research: Studying climate change, analyzing geological features, and monitoring changes in ice caps and glaciers.

Types of imagery:

Optical imagery: Captures images in visible and near-infrared wavelengths, providing detailed information about surface features.

Radar imagery: Uses microwave signals to penetrate clouds and vegetation, making it useful for mapping terrain and monitoring changes over time.

Thermal imagery: Measures infrared radiation emitted by the Earth's surface, useful for detecting heat anomalies and monitoring urban heat islands.

Advantages:

Coverage: Provides global coverage, enabling monitoring of remote and inaccessible areas.

Frequency: Regularly updated images allow for temporal analysis of changes over days, months, or years.

Accuracy: High-resolution imagery provides detailed spatial information for precise analysis and decision-making.

Challenges:

Cloud cover: Optical imagery can be obstructed by cloud cover, limiting visibility during certain times or in regions with frequent cloud cover.

Cost: Acquiring and processing satellite imagery can be costly, especially for high-resolution or specialized data.

Resolution: Lower-resolution imagery may lack detail for certain applications requiring fine-scale analysis. Satellite imagery plays a crucial role in diverse fields by providing valuable spatial information for monitoring Earth's surface, understanding environmental changes, and supporting decision-making processes across various sectors.

Drone technology: Enables aerial surveys of fields at a finer resolution than satellites, capturing detailed images that aid in crop monitoring, pest detection, and yield prediction.

Nutrient management tools:

Precision fertilizer applicators: Use data from soil sensors and historical crop yield maps to apply fertilizers at variable rates across the field, ensuring each area receives the appropriate nutrients.

Variable Rate Technology (VRT): Adjusts the application rate of fertilizers and other inputs based on real-time data and field variability.

Pest and disease monitoring:

Insect traps and monitoring devices: Capture and analyze data on insect populations, helping farmers to implement targeted pest control measures.

Disease detection sensors: Monitor for early signs of diseases in crops, allowing timely interventions to prevent outbreaks.

Crop monitoring and yield mapping:

Yield monitors: Installed on harvesters to collect data on crop yields as they are harvested, generating yield maps that inform future planting decisions and management practices.

Canopy sensors: Measure crop canopy characteristics such as biomass, leaf area index, and chlorophyll content, providing insights into crop health and growth stage.

Data management and decision support systems:

Geographic Information Systems (GIS): Integrates data from various sensors and sources to create spatial maps that guide precision farming practices.

Farm management software: Analyzes and interprets data collected from sensors to generate recommendations for optimizing inputs, improving crop yields, and reducing environmental impact.

Precision cultivation relies on the seamless integration of these tools and sensors to gather accurate, timely data for making informed decisions that enhance productivity, sustainability, and profitability in agriculture.

Fertigation: Fertigation, also known as chemigation, involves injecting fertilizers, soil amendments, and other water-soluble products into an irrigation system.

The two terms are sometimes used interchangeably. Chemigation frequently uses pesticides, herbicides, and fungicides, some of which pose health threats to humans, animals, and the environment.

Fertigation is widely used in horticulture and commercial agriculture. It is also increasingly being used for landscaping as dispenser units become more reliable and easier to use. Fertigation is used to supplement nutrients or to correct nutrient deficiencies detected in plant tissue analysis. It is usually practiced on high-value crops including vegetables, turf, fruit trees, and ornamentals. Several techniques have been developed for applying fertilizers through the irrigation systems and many types of injectors are available on the market.

During irrigation, a liquid fertilizer solution is supplied into the system at low rates and continuously. The injector's flow rate should maintain a constant supply of the calculated solution throughout the irrigation cycle, i.e. starting fertigation right after the system starts operation and finishing a few minutes before the operation ends. When choosing fertilizers, consider solubility, acidity, quantity, and cost, in addition to the amount and type.

There are two major techniques: the ordinary closed tank; and the injector pump.

Closed tank-

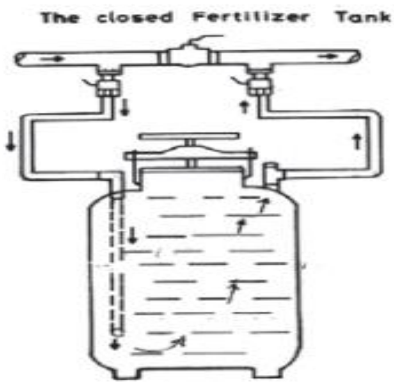
This is a pressurized metal tank that is cylindrical, epoxy coated, resistant to the system's pressure, and connected as a bypass to the supply pipe of the head control.It operates by creating a differential pressure on the pipeline between the tank's input and outflow through a partially closed valve.

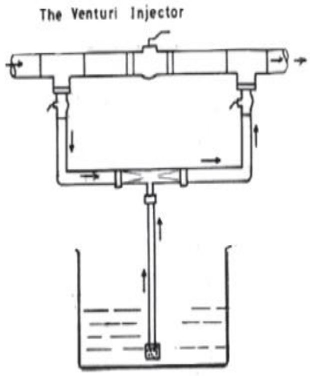
Injector pump-

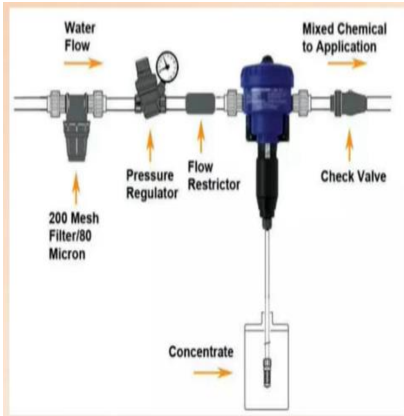
This method has two subtypes:

Venturi type: This is based on the principle of the Venturi tube. There must be a pressure differential between the inlet and the outlet of the injector. Therefore, it's installed on a bypass arrangement, placed on an open container containing the fertilizer solution. The injection rate is highly sensitive to pressure fluctuations, necessitating the use of small pressure regulators for constant ejection. The Plastic injector range in sizes from 2 inches and can handle injection rates of 40–2000 litres/h. They are relatively cheap compared to other injectors.

Piston pump: This kind of injector is powered by the water pressure of the system and can be installed directly on the supply line, rather than a bypass line. The system's flow activates the pistons and the injector is operated, which discharge the fertilizer solution from a container, while maintaining a constant rate of injection. The rate varies from 9 to 2500 litres/h depending on the pressure of the system and it can be adjusted by small regulators. Made of durable plastic material, these injectors are available in a variety of models and sizes.







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SOIL AND WATER CONSERVATION STRUCTURES FOR RESOURCE MANAGEMENT AND REDUCING SOIL EROSION

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Natural resource management

Natural resource management is the management of natural resources such as land, water, soil, plants, and animals, with an emphasis on how management affects the quality of life for current and future generations. management of natural resource is concerned with controlling the interactions between humans and natural landscapes. It integrates planning on land use, managing of water, conservation of biodiversity, and industrial sustainability. It recognises that people and their livelihoods rely on the health and productivity of our landscapes, and that their actions as land stewards are crucial to preserving this health and productivity. Management of natural resource also aligns with the concept of sustainable development. Natural resource management focuses on a scientific and technical knowledge of resources and ecology, as well as the resources' ability to support life.

Types of natural resource management

Water resource management

All terrestrial life requires water to survive. Water resource management is equally important right from understanding the water cycle and how human intervention pollutes water bodies. One must also understand that the study of rainfalls is not enough to understand the whole truth of water resource availability for various regions in India.

- Engineer water treatment systems: using cost-effective infrastructure and ensuring recycling of water by saving energy too.
- Traditional Rainwater harvesting
- Using sustainable methods of irrigation. For example, opting for drip irrigation compared to sprinkle irrigation.
- Focus on the reuse of water.
- Promote sponge cities, i.e, promote mangrove plantations to recharge the groundwater levels.

Land resource management

- Land Resource Management is important from the perspective of current emerging needs for planning, food security, sustainable livelihoods, landscape management and restoration.
- Improving efficiency in the use of land is crucial for agriculture, especially when we consider factors such as soil erosion or soil degradation.
- Recognition of traditional and diversified land use and promote sustainable agricultural techniques to avoid loss of soil nutrients.
- Controlled migration of people can also help in lowering the impact of a possible strain on natural resources for that particular land and diagnosis of socio-economic issues.
- To recognise barren land or degraded land and promote the growth of infrastructure for the same.
- Create and support land resource management policies for a sustainable livelihood

Soil Erosion

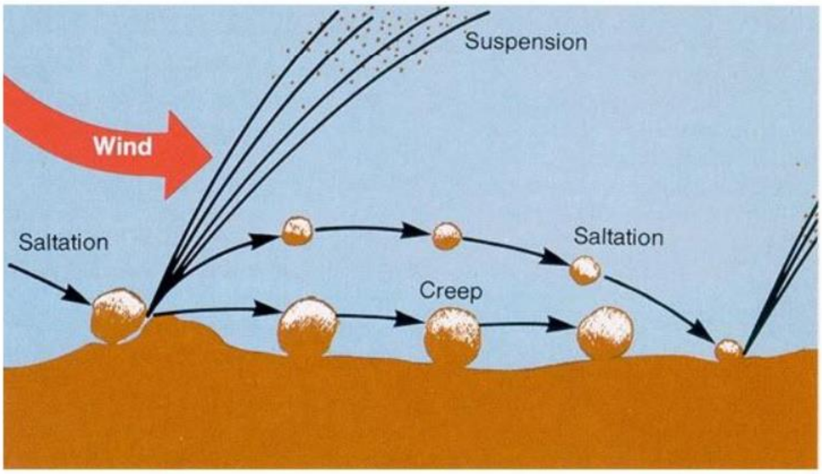
The process by which soil is transported and deposited in different places after being taken from the Earth's surface by exogenetic processes like wind or water flow is known as soil erosion. Generally speaking, soil erosion refers to the physical removal of topsoil caused by a variety of factors, such as wind, rain, water moving over and through the soil profile, glaciers, or gravity. The two most valuable natural resources that sustain and enable human activity are land and water. Approximately 65% of people in India, in particular, are dependent on agriculture, the only industry that both maintains balance of ecology and creates half of all jobs.

Types of soil erosion

Soil erosion can be split into three types based on the eroding agents: water erosion, wind erosion, and chemical or geological erosion. Soil erosion is mostly caused by agents such as water and wind. Erosion generated by chemical and geological causes is a sluggish process that can last for years and is frequently intangible. Water erosion is further classified based on its effects. These include sheet erosion, rill erosion, gully erosion, land slide/slip erosion, and stream bank erosion.

Geologic erosion: Geologic erosion, often known as natural or normal erosion, is erosion that occurs beneath vegetation. It encompasses both soil and soil-eroding processes that keep the soil in a balanced, favourable state for the majority of plant development. Because soil erosion occurs at such a sluggish pace, new soil is created naturally through weathering processes, offsetting the loss of soil. Geologic erosion has resulted in the many topographical characteristics that exist, such as valleys and streams.

Wind erosion: Soil particles are separated, carried, and redeposited by wind; a process known as wind erosion. The risk of wind erosion is increased by broad fields, high winds, a loose, dry, and smooth soil surface, and little or no vegetation cover. To cause deflation and particle transport, air flow must first reach a certain velocity (fast enough to produce observable particle movement at the soil level). Sand-sized particles are seldom dislodged and propelled by winds that reach velocities of less than 12-19 km/hr at the soil's surface. When the wind reaches 25-30 km/h, it is generally the beginning of the drifting of extremely erosive soil. All soils affected by dryness are susceptible to wind erosion, however it tends to happen more often in low rainfall locations when soil moisture content is at or below wilting point. The majority of the soil nutrients are found in an air haze of dust that contains fine mineral and organic soil particles, which is sometimes the sole sign of wind erosion. Improving the soil's structure to prevent wind from lifting the heavier soil aggregates, keeping vegetation to slow down wind speed at the ground's surface, and creating windbreaks are some ways to lessen wind erosion. Additionally, prepare for periods of extreme wind erosion, which usually occur in the summers after dry winters and autumns. Topsoil loss can be seen as rocky or gravelly knolls, thin soils mixed with lighter coloured subsoil, or the presence of calcium carbonate in surface soils.

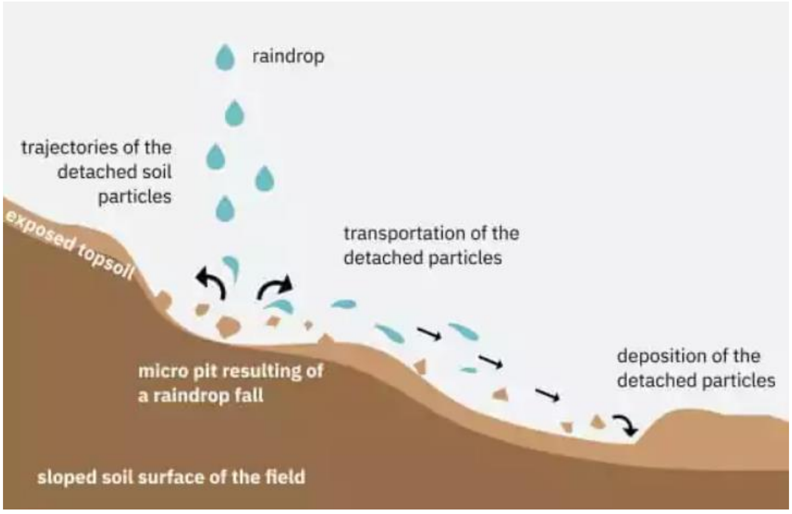


(i) Saltation: Saltation occurs when wind removes bigger particles from the ground over short distances, resulting in sand drifts. Fine and medium-sized sand particles are lifted briefly into the air, displacing more soil as they return to the ground.

(ii) Suspension: Suspension occurs when wind lifts finer particles into the air, causing dust storms. The action of saltation lifts very minute soil particles from the surface and transports them high into the air, where they stay suspended for long periods.

(iii) Surface creep: Large soil particles migrate along the earth's surface after being loosened by the impact of saltating particles.

Water erosion: Water erosion is the process of eroding soil using water as an agent. In water erosion, water acts as a dislodger, transporting eroded soil particles from one site to another.



Types of water erosion

Splash erosion: This sort of soil erosion is caused by raindrops. The kinetic energy of falling raindrops dislodges soil particles, and the resulting runoff carries them. Splash erosion is the first step of soil erosion caused by water. It occurs when raindrops strike bare soil. The explosive impact breaks up soil aggregates, causing individual soil particles to splash over the soil surface. The splattered particles can rise as high as 0.60 metre above ground and travel up to 1.5 metre from the site of impact. The particles clog the gaps between soil aggregates, resulting in a crust that limits infiltration and increases runoff.

Sheet erosion: Sheet erosion is the removal of soil in thin layers through raindrop impact and shallow surface movement. Skimming is a typical activity on agricultural lands. It results in the loss of the finest soil particles, which contain the vast majority of the available nutrients and organic matter in soil. Soil loss occurs gradually, thus erosion generally goes unnoticed, yet the cumulative impact accounts for significant soil loss. This type of soil erosion is primarily responsible for the reduction in soil productivity. Overgrazed and cultivated soils are more prone to sheet erosion since there is little vegetation to protect and hold the soil. Early signs of sheet erosion include bare areas, water puddling when it rains, visible grass roots, and exposed trees.

Rill erosion: Rill formation is the intermittent process that causes gully erosion. The advanced form of the rill marks the first stage in gully formation. The rills are shallow drainage lines that measure less than 30 cm deep and 50 cm wide. They arise when surface water accumulates in depressions or low regions of paddocks, eroding the soil. Rill erosion occurs frequently on bare agricultural land, particularly overgrazed land, as well as newly tilled soil with weakened soil structure. Rills are routinely eliminated using farm machinery. Rill erosion is most widespread in alluvial soils, particularly in India's Chambal River Valley.

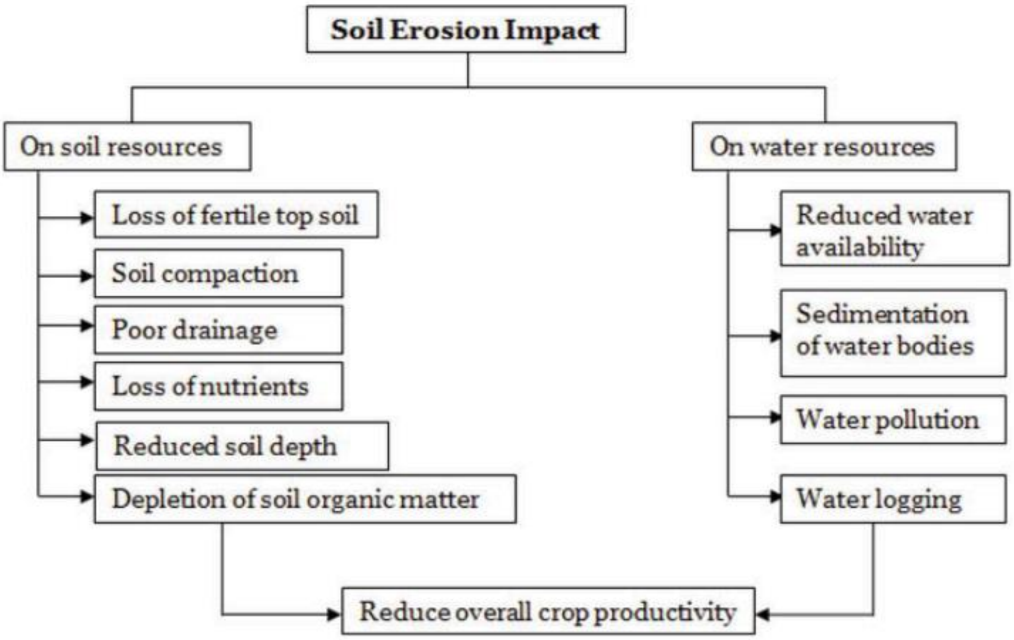
Gully erosion: Gully erosion is the advanced stage of gully erosion. Gully formation occurs when the depth and width of the rill exceed 50 cm. Gullies are deeper channels that cannot be eradicated with conventional cultivation. Hillsides are more vulnerable to gullying when

they are cleared of vegetation due to deforestation, overgrazing, or other causes. After being displaced from the earth, eroded soil is easily carried by flowing water, which occurs most commonly during short, strong storms. The gullies are classified into four groups according to their depth and width: G1, G2, G3, and G4. Gullies impede farming production by cutting into the land and generating sediment that might clog downstream water basins. As a result, more work is needed to understand gullies in the context of geomorphology, to minimise gully erosion, and to repair gullied landscapes. The total soil loss from gully formation and subsequent downstream river sedimentation can be substantial.

Particulars	Description			
	G1	G2	G3	G4
Depth, meter	>=1	1-3	3-9	>9
Width, meter	<18	<18	18	>18
Side slope	<6	<6	6-12	>12

Stream bank erosion: Stream bank erosion occurs when streams begin to remove soil and formation of deeper and wider channels due to increased peak volumes or the removal of neighbouring protective vegetation. Stream bank erosion is common along rivers, streams, and drains when banks are eroded, sloughed, or undercut. This is very prevalent in alluvial rivers and streams. Stream bank erosion becomes a worry when development reduces the meandering nature of streams, streams are channelized, or stream bank equipment (such as bridges and culverts) is placed in areas where it can impact downstream areas. Stabilising these areas can help avoid future sedimentation in watercourses, disrupt other land uses, regulate unwanted meanders, and improve habitat for fish and wildlife.

Effects of soil erosion



Soil erosion has an adverse effect on people's livelihoods in one way or another. The significant losses and problems caused by soil erosion from various factors are outlined below.

1. River siltation.
2. Irrigation channel and reservoir siltation.
3. Improve crop irrigation and conserve water.
4. Damaged the sea coast and formation of sand dunes.
5. Hazards related to disease and public health.
6. Water erosion deposits soil on river beds, leading to increased levels and flooding. Floods can have a wide range of dramatic effects, including the death of humans and animals and the destruction of various structures.
7. Soil erosion depletes moisture supplies for plant growth. The loss of the top layer of soil, which contains the majority of organic matter and nutrients, lowers soil fertility and degrades its structure.
8. Wind erosion is highly selective, transporting the finest particles - mainly organic debris, clay, and loam - for many km. Wind erosion depletes fertile soils in productive farming areas.

9. The most spectacular forms are dunes, which are mounds of more or less sterile sand that move with the wind, burying oases and ancient civilizations.
10. Sand sheets near to the ground (30-50 metres) can harm crops.
11. Wind erosion affects soil nutrient and water storage, leading to a drier climate.

Soil conservation

Soil conservation is the field activity that addresses the issue of soil erosion of any kind, as explained in the preceding lecture. In a larger sense, soil conservation operations reduce soil erosion through the use of several approaches. The ultimate goal of soil conservation is to prevent future soil erosion and maintain agricultural output. The integrated nutrient management is also related with conservation of soil, and it utilises techniques such as soil defect rectification, manure and fertiliser application, suitable crop rotations, irrigation, drainage, and so on, all of which aim to keep soil productivity at a higher level. Soil conservation, on the other hand, is primarily concerned with improving land use and reclaiming eroded land in order to repurpose unused land resources under cultivation while also safeguarding the land resources from future degradation. In other words, soil conservation is effective land husbandry that preserves the land and soil fertility on a long-term basis while also promoting better agriculture, increasing yields, and maximising the benefits of such land. Such land husbandry should be founded on good land utilisation classification and balanced classification of lands for diverse purposes, each of which is appropriate for the local conditions.

Need of soil conservation

1. To continue producing goods from natural resources in order to fulfil the expanding population's fundamental needs for clothes, food, and shelter.
2. To maintain productivity by preserving topsoil, which will lessen the degradation of soil fertility and water-holding ability.
3. To prevent gullies and rills from forming in the field as a result of soil erosion, which lowers productivity.
4. To maintain the soil's ability to retain moisture in order to boost groundwater recharge.
5. To keep the arable area from shrinking and to sustain the productivity of the land.
6. To lessen the amount of dredging required because of sedimentation in lakes, reservoirs, rivers, and creeks.
7. To shield non-point source pollutants from water bodies.

8. To reduce the chance of floods, which has an impact on the sustainability and means of subsistence for people, animals, and plants.
9. To stop the ecosystem from becoming worse because of soil erosion, which causes the nutrient cycle to be disrupted, soil fertility to be lost, flora and fauna to become extinct, soil erosion to occur, etc.
10. To support the environmental systems that have an impact on plant development and forest regeneration.

Approaches of soil conservation

The top soil layer is balanced with organic matter and nutrients, both of which are beneficial to plant growth. To promote greater plant growth, the top soil layer must be shielded from wind and water erosion. Soil conservation measures refer to the steps made to conserve the top layer of soil. These techniques preserve top soil by limiting the impact of erosive factors (water and wind), and also improving soil aggregate stability and surface roughness. Soil conservation measures can be broadly divided into three categories: biological, mechanical, and bio-engineering.

Biological control of soil erosion: In this case, erosion is controlled by crops or vegetation, which is the natural manner of doing things. It means that farming should be done in a suitable manner by using steps to minimise erosion. Improper cultivation causes serious soil erosion. A persistent vegetative cover is the greatest way to protect the soil. Studies have found that bare terrain allows for four times more soil erosion than permanent plant-covered ground. As a result, vegetation plays an essential role in soil erosion management and can be used effectively. In this strategy, we strive to plant species that can keep soil well and thrive in harsh soil conditions. The primary idea of biological control is to prevent the excessive velocity of water and retain water within the soil. In biological control, the following method can be used.

- It prevents splash erosion;
- It reduces the velocity of surface runoff;
- It facilitates accumulation of soil particles;
- It increases surface roughness which reduces runoff and increases infiltration;
- Roots and organic matter stabilise soil aggregates and improve infiltration.

Mulching: Mulching is the process of covering the soil with crop wastes such as straw, corn, and stalks. These covers protect the soil from raindrop impact while also reducing runoff and wind velocity. It can also be used as an alternative to cover crops in dry places where cover crops would compete for moisture with the primary crop. Figure depicts the use of mulch in agriculture.

Agro forestry: Trees can be included into an agricultural system by planting them on terraces, contour lines, and as ornamental plants around the house. This prevents soil erosion and satisfies additional needs for farmers. The figure shows an agroforestry system in which poplars grow alongside turmeric, mango, and litchi.

Reforestation/Afforestation: Reforestation is the process of restocking depleted forests and woods, either naturally or artificially. Reforestation can help to enhance air quality, reduce global warming, and rebuild ecosystems by preventing soil erosion. Forestation/plantation is essential for controlling erosion in gullies and landslides.

Crop rotation: It can be characterised as a more or less regular succession of several crops planted on the same plot of land. Crop rotation decreases erosion and promotes soil fertility by growing multiple crops on the same plot of land, allowing plant nourishment to be absorbed from different layers of soil. agricultural rotation also boosts agricultural productivity and net profit while reducing pesticide use and water pollution. Leguminous crops, such as pulses, are cultivated alternately with wheat, barley, and mustard. depicts the standard layout for a crop rotation system.

Mixed cropping: This strategy involves raising two or more crops on the same area at the same time. Mixed cropping is often called intercropping or co-cultivation. A mixed cropping system provides various advantages, including greater nutrient utilisation, less weeds and insect pests, tolerance to temperature extremes, increased overall productivity, and the most efficient use of limited resources.

Cover cropping: Cover crops are produced as a conservation measure, either in the off-season or to protect the ground beneath trees. These also contribute organic materials to the soil. All of these provide good erosion control cover while also providing hay or fodder and soil-building crops. These cover crops are also grown under trees to protect the soil from the impact of rainfall drops falling from the canopy, which is especially significant for tall trees such as rubber, where the height of fall is greater.

Contouring: Contouring is the process of applying all the tillage practices, such as ploughing, planting, cultivating, and harvesting, across the slope rather than up and down. In low-rainfall locations, this aids in moisture conservation, whereas in humid areas, it decreases erosion by decreasing surface runoff. Contour tillage activities create furrows between ridges that capture and hold water, reducing high water velocity, which erodes soil and creates sheet, rill, or gully erosion. On steep slopes or in areas with high rainfall intensity and soil erodibility, contour farming alone will exacerbate gullying because row breaks may release stored water. Under such situations, strip cropping is used to complement them.

Strip cropping: It is the practice of cultivating row crops alternately with intertilled crops in the same land. Crops are cultivated in strips perpendicular to the land's slope. Erosion is primarily limited to row-crop strips, and dirt lost from these is trapped in the following strip, which is often planted with a leguminous or grass crop. Strip cropping lowers soil erosion caused by water and wind, as well as water-borne pollution. Strip cropping is commonly classified into three types: contour strip cropping, field strip cropping, and buffer strip cropping.

Conservation tillage: Any type of soil cultivation that leaves crop residue on the field both before and after planting the next crop is known as conservation tillage. It reduces runoff, water pollution, soil erosion, greenhouse gas emissions, and the use of fossil fuels. The four types of conservation tillage are mulch-till, ridge-till, strip-till, and no-till. In strip-till, thin strips are tilled while the remaining portion of the field is left tillled; in no-till, crops are planted straight into residue that has not been tilled at all (strip-till). By merely removing crop residues from the ridge tops, row crops grown in ridge-till systems are immediately planted on permanent ridges measuring 10 to 15 centimetres. Any other reduced tillage method that leaves crop residue covering at least one-third of the soil surface is known as mulch-till.

Mechanical methods: Mechanical procedures are engineering techniques used to prevent soil erosion from a sloping land surface. The mechanical structures' objective is to (1) lengthen the time of stay of runoff water, so increasing infiltration time, and (2) break the land slope, thereby reducing runoff water velocity. Bunds and terraces are mechanical structures used to reduce soil erosion.

Bunding

i. **Contour bunding:** Contour bunding is used to conserve soil moisture and reduce erosion in the areas having 2-6% slope and average annual rainfall of <600mm with permeable soils. Bund spacing refers to the vertical distance between two bunds. The spacing of bunds is determined by the erosive velocity of runoff, slope length, slope steepness, rainfall intensity, crop variety, and conservation efforts.

ii. **Graded bunding:** Graded bunds are designed to safely drain surplus runoff water in places with a land slope of 6-10% and rainfall of >750mm and the soils having an infiltration rate of <8mm/h.

iii. **Peripheral bunds:** Peripheral bunds are constructed around the gully head to check the entry of runoff into the gully. It protects the gully head from being eroded away through erosion processes. It creates an ideal environment for the implementation of vegetative measures on gully heads, slopes, and beds.

Terracing

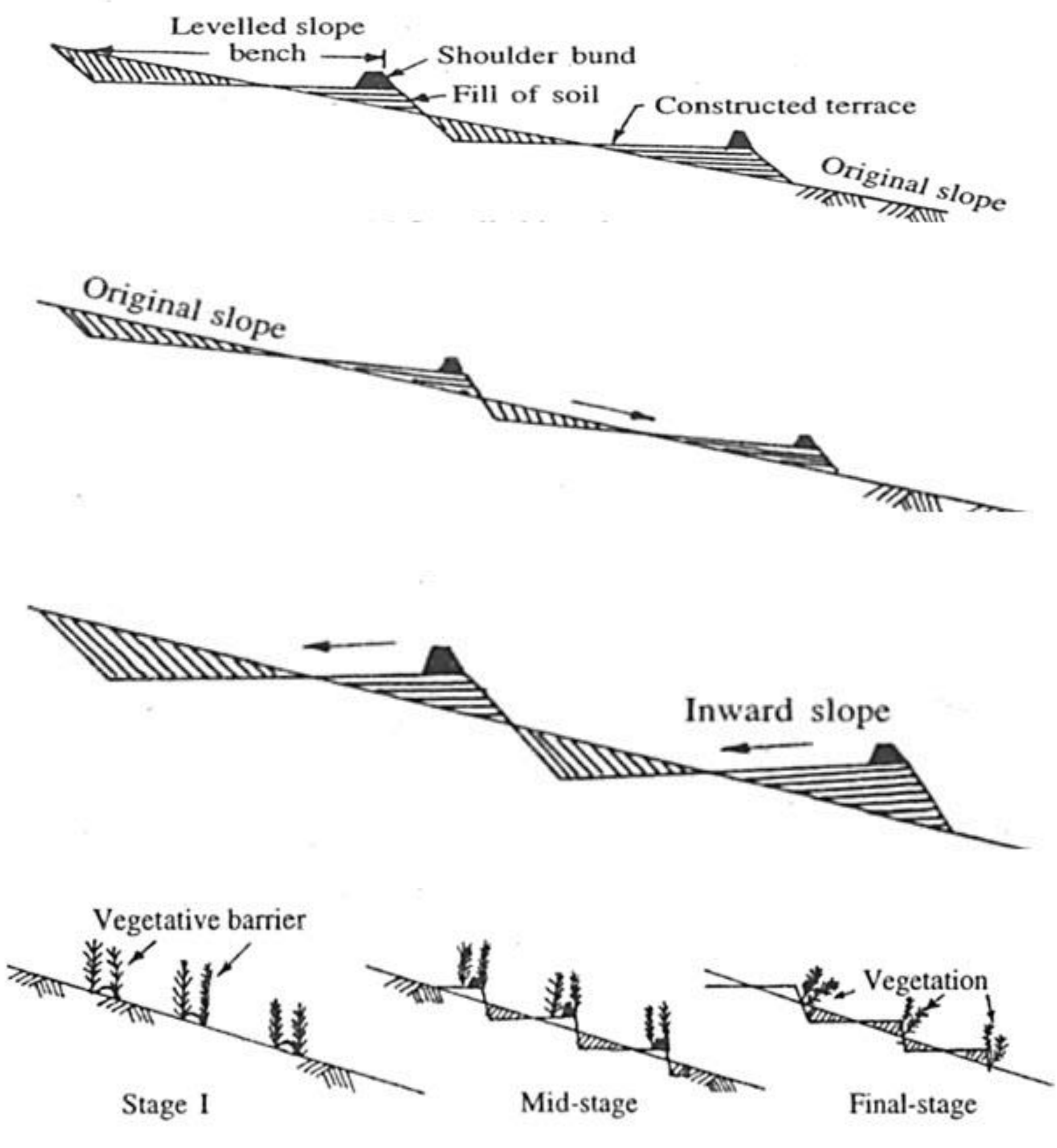
Terraces are earthen embankments built across the main slope to divide the field into regular, parallel portions. Typically, these structures are coupled with channels to transfer runoff into the main exit at slower speeds. It minimises the angle and length of the slope, lowering runoff velocity, soil erosion, and improving water infiltration. It is advised for fields with a slope of up to 33%, but it can also be used for lands with a slope of 50-60%, depending on the socioeconomic conditions of the region. When there are plenty of high-quality stones available, stone bench terracing is recommended. Half-moon terraces are semi-circular terraces placed on the downstream side of plants.

Based on the slope of benches, the bench terraces are classified into the following categories.

i. **Bench terraces with level top:** These terraces are appropriate for uniformly dispersed medium rainfall locations with deep and highly permeable soils. These are often referred to as irrigated bench terraces due to their application in irrigated environments.
ii. **Bench terraces sloping outward:** These terraces are employed in low rainfall locations with permeable soils. A shoulder bund is given to stabilise the edge of the terrace, allowing longer time for rainwater to seep into the soil.
iii. **Bench terraces sloping inward (hill-type terraces):** These bench terraces are appropriate for heavy rainfall situations where a greater amount of the rainwater will

be discharged as runoff. To do this, a sufficient drain should be installed at the inside end of each terrace to drain the runoff. These are also referred to as hill-type terraces.

iv. **Puertorican Type Bench Terrace**: It is also known as California type bench terrace and it is levelled in various stages as shown in fig.



Source: Das, 2002

Contour trenching

Trenches are constructed at the contour line to limit runoff velocity and conserve soil moisture in regions with a slope of less than 30%. Bunds are built on the downstream side of trenches to conserve rainwater. There are two sorts of trenches:

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i. **Continuous contour trenches:** Continuous contour trenches are constructed based on the size of the field in low rainfall locations, with a trench length of 10-20cm and an equaliser width of 20-25cm, with no discontinuity in trench length (10-20m).

ii. **Staggered Contour Trenches (STCs):** In places with considerable rainfall and a high risk of overflow, these ditches are typically built in staggered rows directly beneath one another.

Bio-engineering method: Biotechnical engineering approaches are used in conjunction with biological knowledge to construct geotechnical and hydraulic structures, as well as to stabilise unstable slopes and banks. Whole plants or their pieces are utilised as construction materials to stabilise unstable areas, together with other (dead) construction materials. Biotechnical solutions based on willows and other woody plants are ideal for building a variety of soil conservation structures. This structure stabilises the soil, slows the flow of running water, and so reduces surface erosion. Maintenance of these structures is critical when compared to other techniques of soil conservation.

The maintenance cost of bioengineering structures is somewhat high in initial period and later on it becomes very less. Bio engineering methods of soil conservation have the following advantages.

- Effective after installation
- Easy to use as a nursery for fresh plant material
- Flexible preparation and protection options Bio engineering methods have some disadvantages.
- High material and labour demand
- Occasional thicket thinning
- Labour intensive

Conservation agriculture: Conservation agriculture which involves minimal mechanical soil disturbance and direct sowing, organic mulch cover from residues and cover crops, and crop species variety via rotations and associations, is now practiced on around 125 million hectares worldwide. This technology can help to reduce production costs, save water and nutrients, increase yields, diversify crops, improve resource efficiency, reduce runoff and soil erosion, and benefit the environment. In recent years, India has increased its usage of zero tillage and conservation agriculture to approximately 1.5 million hectares.

Zero tillage: From harvest to planting, no-till leaves the land unaltered. Coulters, row cleaners, disc openers, in-row chisels, and rototillers all make a narrow (usually 6-inch or smaller) seedbed or slot for planting. Zero-till or no-till planting can be done successfully on chemically killed sod or previous year's agricultural leftovers. Soil conservation is achieved because agricultural waste covers a considerable portion of the area.

Ridge tillage: Ridge-tilling is the process of planting seeds into a ridged seedbed prepared with sweeps, disc openers, coulters, or row cleaners. During cultivation, the ridges are rebuilt. From harvest till planting, the ground is completely untouched save for fertiliser injections. Ridge-till works best in soils that are nearly level and poorly drained. Ridge-till systems leave residue between the ridges on the surface. The amount of residue and row direction influence soil conservation. Planting on the contour reduces soil loss significantly while increasing surface coverage.

Mulch tillage: Although the area is tilled using mulch tillage, enough residue remains on the soil surface to significantly reduce erosion. A portion of the crop residue is incorporated into the top few inches of soil. Mulch-tillage is beneficial on a wide range of soils, especially those with poor drainage. This technique improves roughness and infiltration compared to traditional tillage methods.

Advantages of conservation structures: Land and water management bears benefit over a longer time span after construction. However, some benefits such as increased crop yields can be can be attained within the first year. In general, the benefits of SWC can be summarised as follows:

- SWC saves productive land and supports sustainable agriculture. • Increases agricultural productivity through higher yields and livestock feed. • Reduces soil nutrient loss, reducing the demand for fertiliser.
- Environmental preservation through improved soil water storage and catchment hydrology.

- SWC protects roads and infrastructure from erosion, increases irrigation and drinking water supplies by reducing sedimentation in reservoirs, and improves soil drainage in flood-prone areas.

Challenges in Soil and Water Conservation

- Farmers face challenges in making effective investments in land and water management due to fragmented ownership.
- Maintaining conservation structures needs significant effort.
- Floods are a common threat while cultivating crops in semi-arid environments. Farmers find it difficult to completely realise the benefits of conservation as a result.
- Many farmers lack skills in designing and installing conservation buildings, resulting in poorly constructed structures in the field.

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SOM AND SOALU NURSERY RAISING TECHNIQUES: FOREMOST STEP TOWARDS SUCCESSFUL MUGA CULTURE

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Abstract:

Som (*Persea bombycina*) and Soalu (*Litsea polyantha*), are the primary host plants of muga silkworm, *Antheraea assemensis* Helfer. The host plants of muga silkworms are available in nature throughout Assam and its neighbouring states. Som tree is more prevalent in upper Assam and preferred for commercial rearing purposes for produces reeling cocoon. Whereas, Soalu is more common in lower parts of Assam and particularly used for producing seed cocoon. The plants can be propagated both by sexual method and asexual methods. Som and Soalu plants are propagated through mainly seeds. Seeds are usually propagated by fallen excreta of birds with undigested seed scattered over a wide area. Seeds from selected plants ensure production of healthy seedlings. Som can be propagated by both sexual and asexual or vegetative methods. Sexual propagation is done through seedlings, particularly the seed propagation carries a varied population, this to utilize in selection and hybridization. For seed germination certain pre-requisites are needed to be fulfilled such as selection of quality seed, preparation of land, and the seed should be selected such that can definitely germinate. This is possible only when the seed is subjected to suitable environmental conditions, embryo of seed is alive, and healthy, in internal conditions of seed are favourable for germination. The fresh seeds will have greater germination rate than the stored once. Seeds must be washed with fresh water until the flesh of fruit is withdrawn and dried well, however minimum moisture percentage should be maintained, i.e. at least 6%. Sowing of seeds may be by way of broadcasting or sowing in lines. Propagation through seeds is one of the cheapest and easiest methods. Som being a cross-pollinated plant, sexual propagation introduces variability in the progeny and

gives scope for selection of new varieties. It is suitable for large scale multiplication to build up stocks for preparation of grafts. Comparatively long gestation period to provide leaves for silkworm rearing. The desirable traits of improved cultivars cannot be perpetuated. On the other hand, soalu is very easy to grow and multiply via seed, where survivability rate is more than 90%. Vegetative means of propagation includes, cutting, grafting and layering etc. With recent advancements, multiplication through micropropagation and tissue culture etc ahs been tried to enhance the rate of multiplication independent of agroclimatic conditions and seasons. In this chapter, an attempt has been made to collectively enumerate the maximum information to provide a guide for successful som and soalu nursery establishment for muga rearers.

Keywords: Muga, Host Plants, Som, Soalu, Nursery, Seedlings, And Multiplication.

Introduction:

India is the only country producing the shimmering golden Muga silk. It is produced 14 mainly in Assam, and few other North-eastern states (Bindroo *et al.,* 2009). Muga silk is produced by the Muga silkworm is a polyphagous insect which feeds on several host plants. Primarily, it feeds on leaves of Som (*Machilus bombycina*) and Soalu (*Litsaea polyantha*) plants (Saikia *et al.,* 2004). They grow abundantly throughout North-eastern India and in Brahmaputra valley and Garo hills in particular. The other host plants of Muga are of less importance. They are called secondary host plants like, Mejankari (*Litsaea citrala*), Digloti (*Litsaea salicifolia*), Choa (*Magnolia sphenocarpa*), Bhumloti (*Symploces gradifflora*), etc. (Seth, M.K. 2000). The Muga host plants are perennial, Som in Upper Assam and Soalu in Lower Assam. The Som plants are preferred for silkworm rearing due to their long-life span and greater resistance to pest attack. The Som plant called Persea (*Machilus bombycina*) and Soalu plant, scientifically known as *Litsaea polyantha* are evergreen, medium sized tree with spreading branches. Som is identifiable by its rough, dark gray bark, extensively distributed in India, Nepal, Burma, Malaysia and Indonesia (Cordier *et al.,* 2012). It is profusely grown in hill ranges and valleys with humid, warm climatic conditions and also belongs to the family Lauraceae under order Laurales (Yadav and Goswami; 1992). Soalu differs with a woody trunk and rough bark, well distributed in India (lower Assam, Arunachal Pradesh, Meghalaya, Mizoram and Nagaland),

Nepal, Burma, Khmer, Malaysia and Indonesia (Tikader *et al.,* 2013). The tree prefers subHimalayan regions having humid, warm climatic conditions with heavy rainfall.

Selection and preparation of soil:

Soil is the most important element for cultivation of any plant species. Similarly, cultivation of muga primary host plants namely som and soalu starts with selection and preparation of soil.

This section deals with details regarding soil selection and preparation.

Selection of soil:

Site for nursery bed should be selected in a well-drained soil, with low water stagnation and relatively sandy loamy in texture. The soil should be pours to support sufficient gaseous exchange and percolation of water and minerals to deeper layers. Moreover, it will help for root development and spread. Before preparation of nursery bed, soil pH should be tested for acidic or alkaline nature of the soil. As som and soalu prefers sandy loam acidic soils with pH ranging from 4.5 to 5.0.

Preparation of nursery bed:

Layout of bed / Bed size: Well drained and sufficiently irrigated soil should be ploughed upto a depth of 3 to 4 feet for altering the soil layers and should be left as such for sun solarization for 3 days. Afterwards, the soil crumbs should be properly broken and mixed to make a uniform texture of the soil. Equal quantity of cow dung or other organic manures preferably 6 cft FYM can be added to improve the soil fertility levels. The nursery for som and soalu should always be prepared as Raised-bed nursery. The nursery beds should be raised from the ground surface about 4 inches high. The dimensions can be adjusted as per the seedling requirement and seed availability. Generally, 25 x 5ft (length x width) can accommodate 10,000 saplings (Sarmah *et al.,* 2010).

Sowing season:

The seeds of som and soalu are easily available on mature trees during the month of MarchMay. Som seeds are collected during March-April and the Soalu seeds are collected during May-June. The young seeds are green in colour, small in size and round in shape with a circumference of approximately 0.2 micro meter. The ripened seed turns dark in colour and can be harvested during the month of April-May. The seeds are immersed in water. The bottom settled seeds are used for sowing in the nursery beds for raising the seedlings The freshly harvested seeds are then washed in water to remove the pulp and dried in shade for 5 to 8 hours. The viability of som seed lasts for only 10 to 20 days after harvest. Thus, are required to be sown immediately after collection. Seeds are sown in lines in the prepared beds at a spacing of 15 cm in the row and 15 cm between rows at a depth of about 2-4 cm. Sow 2 kg seeds (approx.)/bed (Raja *et al.,* 1993).

Viability of Som seed: There is no dormancy in Som seeds. Freshly harvested seeds have highest germinability. Seed is viable up to 10-20 days after harvesting of seed. The lose viability with the passage of time. The viability of Som seeds loses if preserved for a long period. Viability decreases after 20 days of storage till 45 days.

Selection of viable seeds: The seed quality can be selected by floatation test. Selection of healthy and viable seeds is done by floating the seeds in water. The healthy seeds sink and shriveled and unfertilized seeds float. The pulp of the seeds is washed off by kneading two or three times in running water and dried under shade for a few hours.

Storage of seed: The seeds may, however, be stored in moist seed beds for six to eight weeks under low temperature to prolong their viability. 10°C is the storage temperature of Som seed.

It is desirable to predict the quality of the seeds in respect of germination capacity.

Seed sowing, germination and after care:

Som and soalu seeds are small in size and their shelf life is also very short and are easily perishable, therefor, proper care and handling is utmost to ensure high survival and germination rate. After seed soil, the nursery beds should be covered with thatch or other mulching material to avoid direct sun light exposure that helps to retain moisture in the bed. Germination of Som is 82% (average). Normally one seed gives rise to one seedling only but polyembryonate seedlings are also known to occur. In the polyembryonate seedlings, twins and triplets have been observed in Som which are rare occurrences. The frequencies of twins and triplets are 4.5% and 0.6% respectively. The twins and triplets after separation are capable of developing into independent plants. Som seeds have tough seed coat and requires long duration for germination process that lasts for 3 to 4 months.

Whereas, soalu seeds germinate after 1 to 2 months. The newly germinated seedlings are soft, succulent and delicate. Regular irrigation and other cultural operations like weed management etc. should be done periodically. The seedlings thus raised are transplanted in the field. Seedlings are also raised in polythene bags. The seeds are collected and heaped under a shade covered by gunny cloth with regular water sprinkling to keep them moist. The germination starts after 4 weeks. The germinated seeds are collected and sown in polythene tubes of size 9 x 6 inches size filled with a mixture of soil, sand and FYM at a ratio of 1:1:1 as the rooting medium and allowed for growing. Two to three selected seeds are sown in each polythene tube (15 × 20 cm) filled with the growing medium. After germination on 6th to 8th week from sowing, keep one seedling in each tube and transfer the others. The seeds are kept heaped on moist beds in a shed and covered with wet gunny bags to maintain the moisture and to induce early germination. Then, sowing of germinated seeds into the polythene bags is taken up. Provide a shed over the seedlings to protect them from direct sunlight and hail storm. Remove the shade after the onset of monsoon. At the age of six to eight months, seedlings will be ready for transplantation into the field.

Raising of Som seedlings: Som seedlings can be raised by sowing seed in soil directly or in polytubes.

Transplantation of seedlings to poly tubes:

1. The seedlings can also be raised in polythene tubes. Seedling of 6 months, 10-20 cm (3” to 4”) height is collected for preparation of nursery. The seeds after collection are kept on moist bed under tree shade covered with moist gunny bags followed by sprinkling of water to maintain the moisture. The germination starts after four weeks. The germinated seeds are sorted out every day and sown individually in polythene tubes

   of 9 x 6 inches size of 150-220 guaze, filled with rooting media and kept under tree shade.
2. Rooting media.
3. A mixture of soil, sand and farm yard manure (FYM) in the ratio of 1:1:1 soil: sand:

FYM is used as the rooting media for raising seedlings in the polythene tubes.

4. Seedling survivability: 70-85(%).

Pre- treatment of seeds and Seed dressing:

1. Prior to sowing, soak the seeds for 20-24 hours in water and treat the seeds with Bavistin or Carbendazim @ 2 g/kg seed.
2. For seed dressing Trichoderma pseudomonas @ 20 g/kg seed has been suggested in place of Bavistin.

Muga plants are propagated through stem cuttings, layering and through seed nursery.

I. Through vegetative parts

With the increasing demand of true type varieties and also for optimizing biomass production, the importance of vegetative propagation was felt.

II. Through single leaf and shoot bud cutting

Propagation from stem cuttings is the easiest, most convenient and economic method of vegetative propagation. Vegetative, also called asexual propagation gives very quick growth to the plants. The plants would be dwarfs with abundant branches and leaves. They inherit all the true characteristics of the parents. Cuttings from the branches of 1-1½ years old (but not too old) plants or leaf bud cuttings from the apical portions of tender shoots having a small piece of branch about 4 cm long with only one node and a leaf with 1-active bud are selected for the propagation. Many cuttings may be prepared from a single branch too. It is advisable to prepare cuttings early in the morning from suitable healthy young plants during February to April. In some cases, cuttings may even be prepared during September-October also. The upper cut ends of the cuttings are to be sealed with wax or fresh cow dung to avoid drying or rotting. About 3 cm portions of the cuttings are inserted into the rooting medium consisting of clean river sand in polythene tube (22 x 15 cm). The polythene tubes are arranged in pits measuring 2 x 1 x 0.50 m under a thatched shed. Watering is done regularly and continuously for a period of about 2 months. Nearly 60 % rooting takes place after 55-60 days with 90% post transplantation survival. The seedlings or saplings are allowed to grow in the nursery beds for about 2 years before transplantation.

III. Through juvenile shoot cuttings

Juvenile shoot cuttings are prepared from 30-40 days sprouted shoots from basal portion along with some trunk bark tissues of the pollarded / pruned plants. Such cuttings are treated with 0.10 % Bavistin by dipping in the solution for 2 minutes. The juvenile cuttings are inserted in the rooting medium about 3 - 4 cm deep. Then, the cuttings are sown in the nursery. The nursery beds are kept wet by regular watering for maintaining the desired moisture inside the bed. Initiation of rooting takes place at about 30-40 days with maximum rooting (Chakravorty *et al.,* 2007).

IV. Through air layering

Air layering is generally done during April-June (though it may be prepared in other season also). As air layering method records 81% and 85% rooting in Som and Soalu respectively, this method is also adopted. Generally, 1 to 2 years old shoots of 4-5 years old plants are more suitable for air layering. The leaves are removed from the base of the shoot and then a ring of bark about 2 – 3 cm width is removed without damaging the cambium. The cut surface is treated with 500 ppm Indole Butyric Acid (IBA) for further improvement in rooting. The cut portion is then covered with a mixture of compost, cow dung and soil in 1:1:1 proportion adding some saw dust soaked in water for 24 hours and wrapped with polythene paper. The ends are then tied. Rooting takes place within 50-60 days in Som and 40-50 days in Soalu (Phukon *et al.,* 2006). The portion of the branch below the layering is cut and planted in the nursery. It may also be planted directly in the pot. It is advisable not to select big branches or old trees for preparation of air layering. More number of layers will survive, if 50 % of leaves are removed from them at the time of plantation. The cost of raising layers in nursery is higher than the cuttings.

Cultivation of muga food plants

Muga silkworm is reared on unorganized tall Som and Soalu trees, due to the lack of proper plantation technique. Also, Som and Soalu plants show long gestation period. To overcome these problems and to produce quality foliage, a technique has been evolved for systematic plantation of Som under closer spacing. Well-drained high land is chosen for raising Muga host plants. Healthy saplings are to be transplanted from the nursery during monsoon (May-August) when no watering is required without injuring their main roots. Saplings are removed along with the ball of earth before two weeks of transplantation. It will help in sticking the ball of earth to the root system and settling of the terminal roots at the time of transplantation. While transplanting, the position of the sapling/clone in the nursery is to be maintained as far as possible to avoid physiological imbalance. Transplantation may also be done in other seasons where irrigation facility is available. Ring system of watering during dry months is necessary for better growth of plants. Periodical removal of apical tips is necessary for seedlings/layers/saplings after transplantation. The land is deeply ploughed and pits of 30 cm x 30 cm x 30 cm size are prepared at 3 m x 3 m spacing. The pits are filled with soil mixture prepared by mixing sand, soil and FYM in the ratio of 1:1:1, besides 5 -10 g of 10 % Aldrine dust to prevent termite and ant attack. About 6 months old seedlings are transplanted into these pits (Anonymous; 2005).

Plantation at 3 m x 3 m spacing can accommodate 1111 plants per hectare under new technology as against 156 plants under 8 m x 8 m spacing under traditional practice at farm and rearers' level. The technology on Muga food plant cultivation has been adopted widely throughout the North- East and West Bengal (Kanjilal, *et al.,* 1992). Spacing may vary from 3 – 6 m depending on the slope of the land and its fertility. Plantation with closer spacing will produce more leaves and increase the income of the rearers. Plantation should usually be in the north-south direction so as to obtain direct sunshine for different rows of plants. The wind direction is also to be noted. Diglot plants (a shrub) may be planted in between the rows of Som/Soalu to protect the Muga silk worms falling from Som/ Soalu plants due to strong wind and hailstorm during the rearing period. A separate dwarf plantation (Chawki garden) with some shade trees should also be there to rear the early stages of the Muga worms. Quick growing trees may be planted on western and southern sides of the Muga food plantation to serve as a windbreaker to protect the silkworms. Appropriate compound fencing is also provided for regular systematic plantation. Individual enclosure (ghera) is needed for other plants to protect them from cattle, etc., in young age.

Management of muga food plants

Quality cocoon production largely depends on availability of quality foliage. Proper management of Muga host plant during cultivation yields more production of quality leaves. Light hoeing or ploughing is to be done twice a year in criss-cross manner to control weeds. The fibrous roots which feed on top of soil are pruned out to help the growth of short and healthy shoots of the plants. Regular cultural operations like weeding and loosening of soil around the plant (2 times per year) are carried out. Loosening of soil allows the rain water to percolate deep into the soil and ensures for better aeration in the soil.

Plant management packages evolved are discussed below:

a) **Application of FYM**

Plant nutrients improve the texture of soil, and increases water retention capacity besides multiplication of microbes in the soil. The FYM should be applied by making 15 – 20 cm deep ring around the plant at a distance of 60 cm @ 15 cm3 / plant up to 4th year and 30 cm3 from 4th year onwards. The ring full of FYM is covered with soil to avoid loss of nutrients due to heavy showers and to help in increasing the production of quality leaves. The application of 30 cm3 FYM / year yields 48 % more leaf as compared to control (Dutta *et al.,* 2009). Thus, fertilizers are used in appropriate doses for better growth of plants and production of more leaves.

b) **Application of NPK**

Increased supply of nitrogen increases the crude protein percentage and improves the quality of leaf. Potassium and Phosphorus help in increasing the utilization of Nitrogen resulting in increased production of quality foliage. Application of N:P:K @ 50:25:25 up to

4th year of plantation and @100:50:50 from 4th year onwards is done through ring method during February- March and September- October months. Application of 100:50:50 kg NPK per hectare per year has been found to yield 66 % more leaf as compared to traditional practices. In traditional practices, the plants are always deprived of these inputs. Application of 40 g Nitrogen, 60 g Phosphorus and 15 g Potassium per plant during 1st to 4th year and 80 g N, 120 g P and 30 g K per plant from 5th year onwards in two split doses should be done at the interval of 6 months during March and August every year. NPK can be applied by making rings as in the case of FYM or through holes in the ground (5-6 oblique holes 20 – 30 cm deep made at a distance of 60 cm around the plant) (Choudhury, S.N. 1982). After NPK application, irrigate the plot if there is no rain.

Cultural practices

i) **Pruning**

Pruning means to cut-off parts of a tree to make it to grow better in a systematic manner. Pruning schedule for Som to obtain quality foliage for six different crops for Muga has been evolved. Muga food plants usually grow as tall trees. But, you need dwarf trees with more branches and leaves for rearing Muga silkworms. So, they are to be pruned from an early stage to keep them at a height of about 3 – 4 m.

To get the required shape and height, pruning at height of about one meter would give us the necessary branching and leaves. Removal of terminal buds twice a year at a height of about two meters would also help to get more branches and leaves. Plants pruned during summer become ready for early and late age rearing after 3- 4 months and after 4-5 months in winter pruned plants (Chakravorty *et al.,* 2004). Pruning should not be done during unfavourable seasons. Fresh cow dung is to be applied at the cut end to save them from drying. By pruning in advance, trees will produce leaves of required age and newly hatched worms will start eating tender leaves. As the worms grow, the leaves too will grow and thus worms will get suitable leaves at each stage of their growth. Dry branches and nests of ants, etc., are to be removed from time to time for proper growth of the plants.

ii) **Pollarding**

Pollarding means cutting-off thick tree trunks to allow a thick crown of branches. Pollarding is defined as removal of bio-mass leaving only tree trunk after 6 to 7 years. Pollarding should be done at specific periods so as to synchronize quality leaf production with the rearing period.

The main objective of pollarding is:

1) To increase the foliage.
2) To remove dead or diseased parts.
3) To maintain desirable height and shape of the plant.
4) To establish a functional relationship between different organs of the plant.

Pollarding at a height of 1.50 m above the ground level in Soalu and 2 m in Som at the age of 7 years has been found ideal in March-April and September-October. Clip-off light branches after each rearing. The cut at the time of pruning should be a slanting one to avoid water deposition. Apply cow dung on the pruned/pollard surface of the branches /trunk. Pollarding is also essential to rear the early-stage worm for better rearing results in every brood. Old trees without pollarding and maturing will not yield healthy and nutritious leaves. Leaves will be hard and do not suit their (worms) digestion.

Weed management

Weeds occur at a maximum density of 948 per sq. m in the month of July and minimum density of 291 per sq. m during February-March. The common weeds in Som and Soalu plantations are *Imperata cylindrica, Saccharum spontaneum* and *Borreria* sp. Uprooting of weeds manually is the best way to control the population. Inter-cropping between Som and Soalu plantation also controls the weeds, provides additional income, ameliorates the soil conditions and helps in growth of main plant because of regular cultural operations they receive. The application of weedicides like Glyphosate (41 %) @ 1.60 in 180 litres of water during sunny days with 6 hours post application exposure is found effective in controlling the thatch grass particularly in Som and Soalu plantations (Morris *et al.,* 2002). Weeding and loosening of the soil are to be done before the weeds flower and bear seeds.

Control and management of diseases and pests

It is advisable to adopt clean culture practices to protect a Muga food plant from diseases and pests. Timely removal of weeds, dead leaves and unwanted materials from the plantation/rearing site helps to control disease and pest population. Spraying of chemicals is normally avoided because the agro-chemicals that decompose slowly into the soil contain pesticide residues that cause damage to Muga silkworm cocoon crop (Kim *et al.,* 2012). The major insect pests and diseases of Muga food plant and their control are listed below:

i) Pest/disease damage control gall insect (*Peuropsylla besooni*)

Ugly galls form on both sides of leaf. Application of 0.05% Dimethoate twice at an interval of 15 days before 20 days of rearing.

ii) Stem borer

Bores through the main trunk penetrating the innermost layer and moves upwards causing heavy damage to foliage. Plugging the Borer holes on trees with cotton plugs dipped in 1.50% Nuvan and plastering the same with mud. Light traps for adults in night also are very helpful. iii) Red Ants/ white Ants

Ants attacks the food plants at all stages of growth. The ants even take away the young silkworm larvae. Pouring crude oil emulsion/ Aldrine 30 EC, Aldrine dust (5 %) should be mixed with soil @ 20 kg/ha. The ants can also be controlled by tying a grease coated polythene sheet around the tree trunk.

iv) Rust fungus

Leaves become yellow and unhealthy when the pustules become mature with dark coloured patches on the upper surface and are not suitable for silkworm feeding. Collecting infected leaves and burning them away from the field. Dusting of Sulphur @ 10-12 kg/ha would serve the purpose.

Bush plantation for chawki rearing

Muga silkworm rearing suffers heavy larval mortality during early stages in seed and pre-seed crops due to inclement weather conditions. Therefore, special care needs to be taken during such periods. Improved rearing technology on bush plantation under nylon net has been developed for reducing early instar mortality. This involves maintenance of 15 – 20 % plants at a height of 180 cm with NPK application @ 200:100:100 per hectare and rearing of chawki worms on 120 days old foliage during 'Chotua' crop (February-March) and 90 days old during 'Bhodia' crop (July-August) under nylon net. Rearing of the late-age worms in the remaining 80 % plants results in 40 % and 70 % gain in cocoon production during Chotua and Bhodia crops (Bharali, N. (1985). The technology has been effectively used under Muga Seed Production Units and United Nations Development Programme (UNDP) sponsored schemes by adopted seed rearers.

Replenish nutrients

- Apply Farm yard manure (FYM) at the rate of 0.5 cft (5 kg) /plant/year and inorganic fertilizers @ 40g, 60g & 15 g NPK/plant /year in two equal split doses up to 4th year
- Double the dosage from 5th year onward.

- Dig a circular trench of 6" to 9" deep around 60 cm circumference at the tree base and refill the same with FYM and NPK.
- Apply the inputs during March- April and September- October.

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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR CROP PREDICTION

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Introduction:

1.1 Overview of crop prediction in agriculture

Importance of crop prediction for food security and resource management

Crop prediction is vital for ensuring global food security and effective resource management. With the world's population projected to approach 10 billion by 2050, food demand is expected to rise by 50% from 2012 levels. Accurate crop prediction supports optimal planning for planting, irrigation, and fertilization, helping maximize yields and minimize resource waste. It also plays a crucial role in managing climate change impacts, such as unpredictable weather patterns and extreme weather events. Reliable predictions aid in stabilizing market prices, planning food supplies, and managing supply chains, ensuring food security and effective response to potential shortages.

Historical methods of crop prediction and their limitations

Traditional methods like regression analysis and time series analysis have limitations due to their simplicity and dependence on historical data. Regression models often fail to capture complex relationships between variables, while time series models struggle with large datasets and changing conditions. These methods also face challenges related to data quality and regional specificity, making generalization difficult and adaptation to new environmental factors problematic.

Emergence of modern techniques and technologies

Modern crop prediction has been transformed by integrating advanced technologies such as AI and ML. These technologies analyze extensive datasets from sources like satellite imagery, IoT sensors, and weather data, revealing patterns and interactions that traditional methods miss. Techniques such as deep learning and ensemble methods improve prediction accuracy by processing high-dimensional data and combining multiple models. Innovations like the Normalized Difference Vegetation Index (NDVI) enhance precision by providing real-time data on crop health and environmental conditions.

1.2 Role of AI and Machine Learning in Modern Agriculture

Brief introduction to AI and ML concepts

Artificial Intelligence (AI) aims to replicate human intelligence in machines, encompassing various techniques from rule-based systems to advanced neural networks. Machine Learning (ML), a subset of AI, focuses on developing algorithms that learn from data to make predictions or decisions without explicit programming. In agriculture, AI and ML analyze data from satellite images, weather forecasts, and soil sensors to develop predictive models for crop yields, resource optimization, and pest detection. ML algorithms, including decision trees, support vector machines, and neural networks, handle complex, non-linear relationships, offering more accurate predictions and insights.

How AI/ML is revolutionizing crop prediction

AI and ML enhance crop prediction by integrating data from multiple sources for precise, real-time insights. Unlike traditional methods, AI/ML models use satellite imagery and IoT sensors to forecast yields and optimize resource use. Techniques such as Convolutional Neural Networks (CNNs) analyze vegetation health from satellite images, while Recurrent Neural Networks (RNNs) model crop growth over time. AI-driven tools also aid in pest and disease management by detecting early signs and predicting their spread. Precision agriculture, powered by AI, enables targeted resource application, reducing waste and environmental impact.

1.3 Objectives of the chapter

Purpose and scope

This chapter explores how AI and ML are transforming crop prediction, covering theoretical foundations, applications, and impacts on agricultural practices. It addresses core concepts, model development, innovations, and practical implications for farmers and the industry.

Key questions and challenges addressed

1. **Core concepts**: What are the fundamental principles of AI and ML, and how do they apply to crop prediction?
2. **Model development**: How are AI/ML models developed, validated, and optimized in agriculture?
3. **Advancements**: What are the latest innovations in AI/ML for crop prediction, and how are they implemented?

4. **Challenges**: What are the limitations and challenges of AI/ML in crop prediction, including data quality, model interpretability, and adoption issues?

The chapter aims to provide a comprehensive understanding of AI and ML in crop prediction, highlighting opportunities and addressing challenges facing these technologies.

2. Foundations of AI and machine learning

2.1 Understanding AI and ML

Definitions and core concepts

Artificial Intelligence (AI) strives to create systems that perform tasks requiring human-like intelligence, such as learning and problem-solving. Machine Learning (ML), a subset of AI, develops algorithms that enable computers to learn from data and make decisions without explicit programming. ML is categorized into three main types:

- **Supervised learning**: Uses labeled data to train models mapping inputs to outputs, useful in crop yield prediction.
- **Unsupervised learning**: Trains models on unlabeled data to find hidden patterns, used for tasks like clustering soil types or detecting unusual pest activity.
- **Reinforcement learning**: Learns by interacting with its environment and receiving feedback, useful for optimizing decisions like irrigation scheduling.

Differences between AI, ML, and deep learning

- **Artificial Intelligence (AI)**: The broad field focused on creating systems with human-like intelligence, including various techniques.
- **Machine Learning (ML)**: A subset of AI that develops algorithms to enable machines to learn from data. It forms the basis of many modern AI applications.
- **Deep Learning (DL)**: A specialized ML subset using neural networks with multiple layers to model complex patterns. DL excels in tasks such as image recognition and is applied in agriculture for analyzing satellite imagery and predicting crop health.

2.2 Machine learning algorithms in agriculture

Overview of commonly used algorithms

- **Decision trees**: Split data based on feature values, used for classification tasks like predicting crop disease likelihood.
- **Support Vector Machines (SVMs)**: Classify data by finding the optimal hyperplane separating classes, effective but computationally intensive.
- **Neural networks**: Capture complex patterns, with deep learning models advancing precision farming.

- **Random forests**: Combine multiple decision trees to enhance accuracy and reduce overfitting, effective for large datasets.
- **K-Nearest Neighbors (KNN)**: Classify based on nearby points, used for soil classification and disease prediction but computationally expensive with large datasets.

Comparison of algorithms

- **Accuracy**: Deep learning models generally offer the highest accuracy, particularly with complex data, but require substantial computational resources. SVMs and random forests also provide high accuracy but need careful tuning.
- **Speed**: Decision trees and KNN are faster to train and predict but may be less accurate for complex tasks. Neural networks and SVMs are accurate but often need more time to train.
- **Scalability**: Random forests and deep learning models handle large datasets effectively. SVMs scale well but can struggle with extremely large datasets, while decision trees may overfit with large data.

2.3 Data science in agriculture

Importance of Data in AI/ML models

Data is crucial for AI and ML models, significantly impacting their performance. In agriculture, data from various sources helps optimize yields, manage resources, and mitigate risks. High-quality data enables models to identify patterns and make accurate predictions.

Types of data used in crop prediction

1. **Weather data**: Critical for understanding how conditions like temperature and precipitation affect crops, aiding in yield prediction and risk identification.
2. **Soil data**: Includes metrics like pH and moisture, essential for optimizing fertilization and predicting yields. Real-time sensor data informs models.
3. **Satellite imagery**: Provides insights into crop health and land use via technologies like NDVI, with AI models analyzing these images to assess environmental impacts.
4. **Genomic data**: Predicts crop traits like disease resistance and yield potential, aiding in developing resilient crop varieties.
5. **Economic data**: Involves market prices and costs, influencing resource allocation and profitability. AI models using this data optimize farming practices.

6. **IoT sensor data**: Real-time data from field sensors monitor conditions and inform recommendations for irrigation and pest control, enhancing farming efficiency.

Understanding AI and ML, their algorithms, and the data they utilize is essential for advancing agricultural practices through precision and efficiency.

3. Data collection and preprocessing for crop prediction

3.1 Data sources

Effective crop prediction relies on diverse data sources, which enhance model accuracy through varied insights:

- **Meteorological data**: Includes temperature, rainfall, humidity, and wind speed. This data, from weather stations, satellites, and IoT devices, helps track trends and make real-time adjustments.
- **Remote sensing data**: Satellite imagery and drones provide critical insights into crop health, soil conditions, and land use. Techniques such as NDVI evaluate vegetation health, while drones detect issues like nutrient deficiencies early (Zarco-Tejada *et al.,* 2019).
- **Soil and crop health data**: Soil pH, nutrient levels, and moisture, along with crop growth stages and chlorophyll content, are vital for optimizing agricultural practices. Technologies such as spectrometry offer real-time insights into these factors.

3.2 Data preprocessing techniques

Preprocessing is essential for reliable crop prediction models, involving:

- **Cleaning and normalization**: Correcting errors and scaling data ensures consistent contributions from all features (Jain *et al.,* 2021).
- **Feature selection and engineering**: Choosing relevant features and creating new ones, like heat indices from temperature and humidity, improves model performance (Khalil *et al.,* 2020).
- **Handling missing data and outliers**: Methods include imputation, deletion, or interpolation for missing data, and techniques like z-score analysis for outliers (Sarker, 2021).

3.3 Integrating diverse data sources

Combining data from varied sources presents challenges but is crucial:

- **Data incompatibility**: Different formats and time frames require careful transformation and synchronization.

- **Data quality**: Ensuring consistent quality across sources is vital for accuracy.
- **Scalability**: Large data volumes from diverse sources often require scalable solutions like cloud computing.

Techniques for data fusion and aggregation:

- **Spatial data fusion**: Combines spatial data using techniques like image registration.
- **Temporal data fusion**: Integrates data with varying time frequencies using interpolation.
- **Multisensor data fusion**: Merges data from various sensors to provide detailed environmental representations using methods like Kalman filtering and Bayesian inference (Dey *et al.,* 2022).

4. AI/ML model development for crop prediction

Developing AI/ML models involves selecting and designing models, training and validating them, and evaluating their performance.

4.1 Model selection and design

Criteria for selecting models:

- **Data type and size**: Time-series data suits models like ARIMA or LSTM, while complex datasets may require deep learning models such as CNNs or RNNs.
- **Model complexity and interpretability**: Complex models capture intricate patterns but may lack interpretability, whereas simpler models offer clearer insights but may not handle complexity as well.
- **Performance and scalability**: Models like Random Forests and Gradient Boosting Machines are accurate but resource-intensive, while simpler models are less demanding but potentially less effective.

Building models:

- **Custom models**: Offer tailored solutions but require significant expertise and development time.
- **Pre-built frameworks**: Tools like TensorFlow and PyTorch provide efficient solutions, often combined with custom components.

4.2 Training and validation

Training data and cross-validation:

- **Training data**: Must be representative of the problem domain.

- **Cross-validation methods**:
    - **k-fold cross-validation**: Divides data into k subsets for robust performance estimates.
    - **Leave-One-Out Cross-Validation (LOOCV)**: Uses each sample as a validation set, though computationally intensive.
    - **Stratified cross-validation**: Ensures consistent target variable distribution, useful for imbalanced datasets.

Hyperparameter tuning and model optimization:

- **Hyperparameter tuning**:
    - **Grid search**: Evaluates all combinations but is computationally expensive.
    - **Random search**: Samples a subset, often more efficient.
    - **Bayesian optimization**: Uses probabilistic models for optimization.
- **Model optimization**: Includes regularization, early stopping, and pruning to enhance performance.

4.3 Model evaluation

Metrics:

- **Root Mean Squared Error (RMSE)**: Measures squared deviations between predictions and actual values.
- **Mean Absolute Error (MAE)**: Calculates average absolute differences, useful for interpreting errors.
- **R-squared (R^2)**: Represents variance explained by the model but may be misleading with non-linear models.
- **F1 score**: For classification tasks, balances precision and recall.

Validation techniques:

- **k-fold cross-validation**: Uses different data subsets for comprehensive evaluation.
- **Bootstrapping**: Estimates performance variability through repeated sampling.
- **Holdout method**: Splits data into training and testing sets, though less reliable for small or non-representative datasets.

5. Advanced AI/ML techniques in crop prediction

5.1 Deep learning and neural networks

Applications:

- **Convolutional Neural Networks (CNNs)**: Analyze spatial data for detecting plant health issues, land-use classification, and early disease detection.

- **Recurrent Neural Networks (RNNs)**: Handle sequential data to predict weather patterns and crop growth cycles, improving forecasts for yield and harvest timings.

Use Cases:

- **Disease detection**: CNNs detect plant diseases from images, allowing early intervention.
- **Crop classification**: CNNs classify crops using remote sensing data, aiding in large-scale monitoring.

5.2 Ensemble learning methods

Techniques:

- **Random forest**: Builds multiple decision trees, effective for yield prediction and classification.
- **XGBoost (Extreme gradient boosting)**: Optimizes predictions by sequentially correcting errors, handling imbalanced datasets.
- **Stacking**: Combines models using a meta-model to enhance accuracy, useful for complex scenarios.

Improvements:

- **Reduction of variance**: Methods like Random Forest reduce overfitting.
- **Handling non-linearity**: XGBoost captures non-linear relationships, improving accuracy.
- **Improved generalization**: Stacking enhances predictions across different conditions.

5.3 Reinforcement learning in agriculture

Emerging use cases:

- **Irrigation management**: Optimizes schedules based on real-time data, improving water efficiency.
- **Pest control**: Develops strategies balancing crop protection with environmental impact (Moallemi *et al.,* 2021).
- **Adaptive fertilization**: Enhances nutrient application based on current data (Jin *et al.,* 2020).
- **Crop rotation planning**: Creates adaptive plans for long-term yields and soil health.
- **Harvest timing**: Determines optimal harvest times, maximizing profitability.

Advanced AI/ML techniques are transforming crop prediction, offering precise, efficient, and adaptive solutions for modern agriculture.

6. Real-world applications and case studies

6.1 Global case studies

Wheat yield prediction in india

- **Institution:** International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- **Technology:** Utilized machine learning algorithms like Random Forest and Gradient Boosting with satellite images, historical weather data, and soil moisture.
- **Impact:** Enhanced predictions led to optimized fertilizer and irrigation practices, boosting wheat production and food security.

Maize prediction in the USA

- **Institution:** University of Illinois
- **Technology:** Applied Convolutional Neural Networks (CNNs) on satellite imagery and weather data from USDA and NASA.
- **Impact:** Improved planning for planting, fertilization, and harvesting, enhancing supply chain management and market predictions.

6.2 Tools and platforms

TensorFlow

- **Features:** Open-source library for a range of models from simple regressions to complex deep learning, integrates with Google Cloud for large-scale data processing.

Google earth engine

- **Features:** Cloud-based platform providing extensive satellite imagery and geospatial datasets, crucial for crop monitoring and land use classification.

IBM Watson

- **Features:** AI tools for predictive analytics in agriculture, including natural language processing and machine learning for weather patterns and agricultural practices optimization.

6.3 Success stories

Climate fieldview by the climate corporation

- **Technology:** Uses AI/ML for insights into field variability and yield predictions by integrating weather forecasts, soil sensors, and satellite imagery.
- **Impact:** Improved crop yields, optimized input usage, and better management of planting and harvesting schedules.

Syngenta's AI-powered crop protection

- **Technology:** AI-driven platform for detecting crop diseases and pests using image recognition and predictive analytics from field sensors and drones.
- **Impact:** Enhanced disease and pest detection accuracy, reduced chemical usage, and improved crop health and yield stability.

Lessons learned and best practices:

1. **Integration of data sources:** Combining diverse data sources enhances decision-making.
2. **User training:** Essential for effective use of AI/ML tools.
3. **Continuous improvement:** Regular model updates are necessary to maintain accuracy.

7. Latest technologies and innovations

7.1 Integration of IoT with AI/ML

Role of IoT sensors

- **Key developments:** Modern IoT sensors for soil moisture, temperature, and humidity enable continuous, high-resolution data collection.
- **Predictive models:** AI models using time-series analysis and RNNs process real-time data for predictions about crop health and yield, optimizing resource use.

7.2 Use of edge computing

Benefits of edge computing

- **Advantages:** Reduces latency with local data processing, enhances bandwidth efficiency, and reduces data transfer costs.

Case Study: CropX smart soil sensors

- **Technology:** Uses edge computing for immediate adjustments in irrigation and nutrient application.
- **Impact:** Optimized water and fertilizer use, increasing crop yields and reducing environmental impact.

7.3 Satellite imagery and geospatial data

Advances in satellite imagery

- **Technological progress:** High-resolution satellites like Sentinel-2 and Landsat 8 provide detailed imagery for monitoring crop health and soil conditions.
- **Integration:** AI models incorporating geospatial data enhance prediction accuracy and farming practices.

8. Challenges and limitations

8.1 Data quality and availability

Issues:

- **Accuracy:** Errors from sensor malfunctions or environmental factors.
- **Availability:** Scarcity of comprehensive and up-to-date data, especially in remote areas.
- **Consistency:** Challenges in integrating data from various sources.

Regional disparities: Advanced technologies are often limited to developed regions, while many areas lack adequate infrastructure.

8.2 Model interpretability

Challenges:

- **Complexity:** Deep learning models can be difficult to interpret.
- **Explanation:** Transparent models are needed for user trust and actionable insights.

Importance: Explainable AI (XAI) enhances model transparency, crucial for effective agricultural decision-making.

8.3 Ethical and social implications

Concerns:

- **Data privacy:** Protecting sensitive data from misuse.
- **Bias:** AI models may perpetuate biases from training data.

Impact: AI/ML technologies can improve efficiency but may exacerbate inequalities if access is limited.

9. Future directions and trends

9.1 Emerging AI/ML techniques

Generative Adversarial Networks (GANs)

- **Applications:** Synthetic data generation for training AI models, enhancing data robustness and accuracy.

Transfer learning

- **Applications:** Fine-tuning pre-trained models for specific agricultural tasks, reducing data and computational needs.

Federated learning

- **Applications:** Allows decentralized model training while protecting data privacy and improving model generalization.

Impact: Enhancements in data availability, model accuracy, and privacy through these techniques.

9.2 AI for sustainable agriculture

Role of AI:

- **Applications:** Optimizes resource use, predicts pest outbreaks, and supports conservation practices.
- **Strategies:** Promotes efficient resource use and supports practices like conservation tillage and crop rotation.

9.3 Policy and regulatory considerations

Key considerations:

- **Funding and support:** Necessary for fostering AI development in agriculture.
- **Education and training:** Important for effective AI tool use.

Regulatory frameworks:

- **Data privacy:** Protecting farmers' data and ensuring ethical use.
- **Ethical guidelines:** Preventing misuse and ensuring equitable benefits.
- **Standardization:** Ensuring interoperability and reliability.

10. Conclusion

10.1 Summary of key points

The chapter highlights the transformative impact of AI and ML in crop prediction through:

- Integration of diverse datasets and sophisticated techniques improving accuracy and efficiency.
- Evolution of machine learning algorithms leading to robust prediction models.
- Innovations in IoT, edge computing, and satellite imagery advancing predictive capabilities.

10.2 Implications for agriculture

- **Increased efficiency:** AI/ML improves resource management and crop yields.
- **Enhanced food security:** Better predictions support planning and risk management.
- **Economic benefits:** AI solutions reduce costs and increase profitability.

10.3 Final thoughts

Future potential:

- **Innovative applications:** Autonomous farming, advanced breeding, and personalized practices.

- **Global collaboration:** Driving further advancements through data sharing and collaboration.

Challenges:

- **Data privacy and security:** Ensuring protection and addressing ownership concerns.
- **Technology adoption:** Bridging the gap between advancements and practical use.
- **Ethical considerations:** Ensuring equitable access and ethical AI use.

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APPLICATION OF REMOTE SENSING FOR PEST MANAGEMENT IN PRECISION AGRICULTURE

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Introduction:

The present review provides a perspective angle on the historical and cutting-edge strategies of remote sensing techniques and its applications, especially for insect pest and plant disease management. Remote sensing depends on measuring, recording, and processing the electromagnetic radiation reflected and emitted from the ground target. Remote sensing applications depend on the spectral behaviour of living organisms. Today, remote sensing is used as an effective tool for the detection, forecasting, and management of insect pests and plant diseases on different fruit orchards and crops. The main objectives of these applications were to collect data that help in decision-making for insect pest management and decreasing the environmental pollution of chemical pesticides. Airborne remote sensing has been a promising and useful tool for insect pest management and weed detection. Furthermore, remote sensing using satellite information proved to be a promising tool in forecasting and monitoring the distribution of locust species. It has also been used to help farmers in the early detection of mite infestation in cotton fields using multi-spectral systems, which depend on colour changes in canopy semblance over time.

Remote sensing can provide fast and accurate forecasting of targeted insect pests and subsequently minimizing pest damage and the management cost. Use of remote sensing for pest and disease management is technically nothing new: the practice of detecting outbreaks with aerial imagery has been documented as early as the 1920s. Though the technology that supports remote sensing has of course come a long way in the past 100 years, it can be difficult for growers to sort through the conflicting information about what's currently possible and practical to achieve in the field.

What is remote sensing

Remote sensing is the technology which refer to the observing any object on the surface of earth either from a aircraft or satellite and taking record of colour diffraction patterns from various crops and its neighboring environment including in field survey.

Components of remote sensing

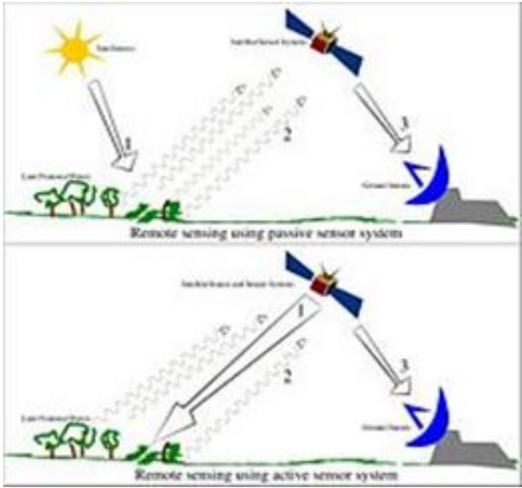
- Platform: structure or vehicle on which the remote sensing structure is mounted.
- Sensor: detecactive reflected radiations and emit active radiations.

It is of two types: Active sensors and Passive sensors. Active sensors use photographic, electro-optic radiometres, visible and infrared radiations and thermal imaging. Passive sensors use RADAR and LiDAR to detect the ground surface objects.

It also captures radiations in two forms: Imaging and Non-imaging

- Data collection: It is done on large computer softwares and classified as required.
- Interpretation and observation of data.

Principal of remote sensing



Detection and discrimination of objects or surface features mean detecting and recording of radiant energy reflected or emitted by objects or surface material. Different objects return different amount of energy in different bands of the electromagnetic spectrum, incident upon it. The Remote Sensing is basically a multi-disciplinary science which includes a combination of various disciplines such as optics, spectroscopy, photography, computer, electronics and telecommunication, satellite launching etc. All these technologies are integrated to act as one complete system in itself, known as Remote Sensing System. There are a number of stages in a Remote Sensing process, and each of them is important for successful operation.

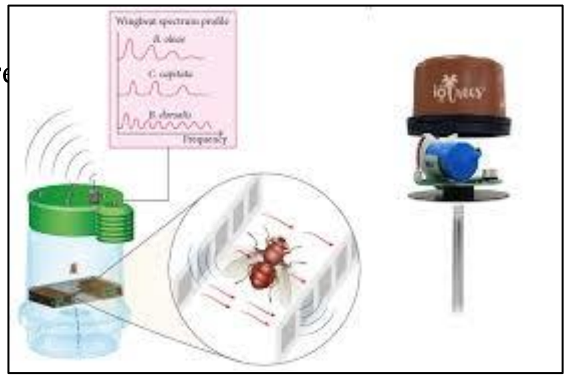
Types of remote sensing

- **Passive remote sensing system**: A passive remote sensing system possesses only a sensor. It does not produce radiations to irradiate the object to be sensed. For example human eye or photographic camera without flash. These can only perceive objects when they are irradiated by sunlight or electricity, but they don't produce radiations themselves.

- **Active remote sensing system**: Active remote sensing system possesses the sensor and also throws the light on the object to be sensed. In other words it also contains the source of signal e.g. photographic camera with flash. In sunlight it can utilize natural radiation for sensing the object but during dark it produces radiation to irradiate the object.

Pest survillance

Refers to constant watch pest and its natural enemy population dynamics, its incidence and damage on each crop at fixed intervals to forewarn the farmers to take up timely crop protection measured.



There are three basic components of pest surveillance are

- The level of incidence of the pest species.
- The loss caused by the incidence.
- The economic benefits, the control will provide.

Case studies

Plant hoppers and leaf hoppers

Prasannakumar *et al.* (2013) in India used hyperspectral remote sensing to detect the brown planthopper (BPH), *Nilaparvata lugens* (Stal.), stress on rice plants under glasshouse as well as field conditions.It revealed that variation in plant reflectance due to BPH damage was smaller at shorter wavelengths (350-730 nm) and larger at longer wavelengths, viz., NIR (740-925 nm) followed by mid infrared (MIR) (926-1800 nm), which indicated the possibility of detection of BPH stress on rice and thereby issuing prompt forewarning to stakeholders.

Moth flight:

It is extremely difficult to observe and quantify high altitude insect movements using traditional entomological techniques. Special purpose entomological radars in the late 1960s (Schaefer, 1976) have greatly added to our knowledge of insect flight behavior at high altitudes. RADAR observation of *Spodoptera exempta* have shown that this species at least in its gregarious phase is an obligate wind borne migrant and that the aggregation of flying moths, particularly by storm front outflows, is a major factor in the outbreak of caterpillars. By contrast, *Heliocoverpa armigera*, in India shows little tendency to undertake long range migration above the altitude at which wind speed exceeds flying speed.

Locusts:

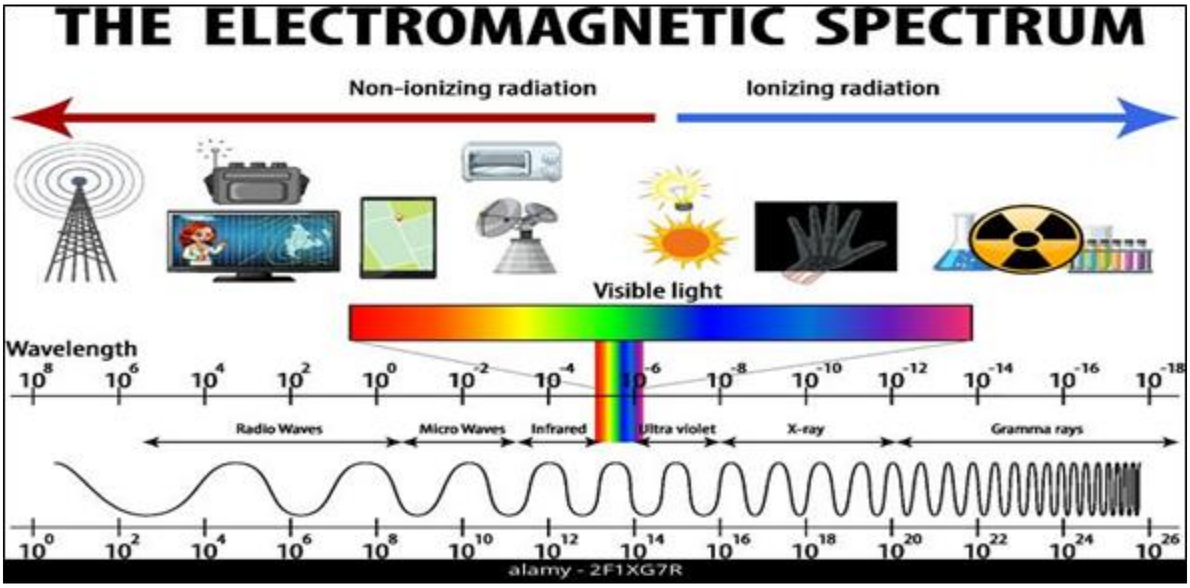
Traditional ground locust surveys are inadequate to address the enormous spatial scale of the locust problem in a limited window of time dictated by the pest's development. Remote sensing (satellite information) appears a promising tool in locust monitoring. Satellite data are increasingly used for monitoring and forecasting two locust species, the desert and the Australian plague locust (Latchininsky, 2013).

Objectives of pest surveillance

- To know existing and new pest species.
- To asses pest population and damage at different growth stage of crop.
- To study the influence of weather parameters on insect-pest population densities.
- To study changing pest status (minor to major).
- To assess natural enemies and their influence on pests.
- Effect of new cropping pattern and varieties on pest.

Electromagnetic spectrum

From remote sensing point of view Infrared and visible bands of electro-magnetic spectrum are important. The wavelength of infra-red (IR) region varies from 3 micro meter - 3mm. IR is further divided into far IR (7-15 pm), mid IR (1.3-3.0 pm) and near IR (0.72-1.3 pm). The wavelength of visible region lies from 0.4-0.7 pm. Far IR is also called emissive or thermal portion of electromagnetic spectrum. Because these radiations first heat the object and then the object emits the radiation. On the other hand, mid IR, near IR and visible regions together are called reflective portion of em-spectrum as these simply reflected by the objects.

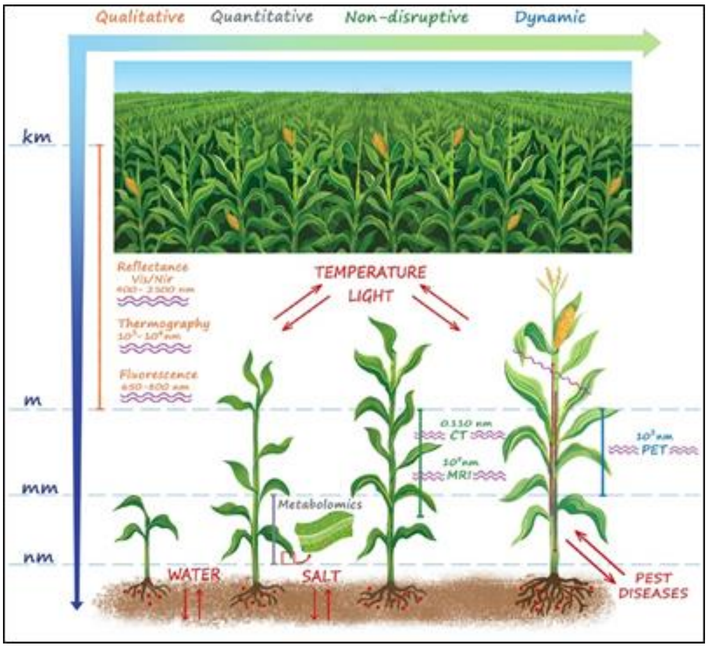


Stages in remote sensing

- Emission of electromagnetic radiation, or EMR (sun/self- emission)
- Transmission of energy from the source to the surface of the earth, as well as absorption and scattering
- Interaction of EMR with the earth's surface: reflection and emission
- Transmission of energy from the surface to the remote sensor
- Sensor data output

Spectral reflectance of vegetation

- Three important factors affecting spectral reflectance of vegetation are:
  - Plant pigments
  - Leaf structure
  - Total water content
- External factors, which influence spectral reflectance of vegetation are:
  - Moisture stress
  - Soil nutrients
  - Salinity
  - Pests
  - Seasonal variation



- The spectral reflectance of healthy vegetation crop is characterized by:
  - High absorption i. e. low reflectance in blue and red regions of em spectrum.
  - High reflectance in near IR due to internal cell structure.
  - Water absorption bands i. e. low reflectance in the mid IR.

Milestones in the History of Remote Sensing

- 181800 Discovery of Infrared by Sir W. Herschel
- 39 Beginning of Practice of Photography
- 1847 Infrared Spectrum Shown by J.B.L. Foucault
- 1859 Photography from Balloons
- 1873 Theory of Electromagnetic Spectrum by J.C. Maxwell
- 1909 Photography from Airplanes
- 1916 World War I: Aerial Reconnaissance

- 1935 Development of Radar in Germany
- 1940 WW II: Applications of Non-Visible Part of EMS
- 1950 Military Research and Development
- 1959 First Space Photograph of the Earth (Explorer-6)
- 1960 First TIROS Meteorological Satellite Launched
- 1970 Skylab Remote Sensing Observations from Space
- 1972 Launch Landsat-1 (ERTS-1): MSS Sensor
- 1972 Rapid Advances in Digital Image Processing
- 1982 Launch of Land sat -4:New Generation of Land sat Sensors:TM
- 1986 French Commercial Earth Observation Satellite SPOT
- 1986 Development Hyper spectral Sensors
- 1990 Development High Resolution Space borne Systems
- First Commercial Developments in Remote Sensing
- 1998 Towards Cheap One-Goal Satellite Missions
- 1999 Launch EOS: NASA Earth Observing Mission
- 1999 Launch of IKONOS, very high spatial resolution sensor system
- 2007 World View-1, (Digital Globe Constellation)
- 2008 World View-2, (Digital Globe Constellation)
- 2009 Earth Explorers, (Soil Moisture and Ocean Salinity)

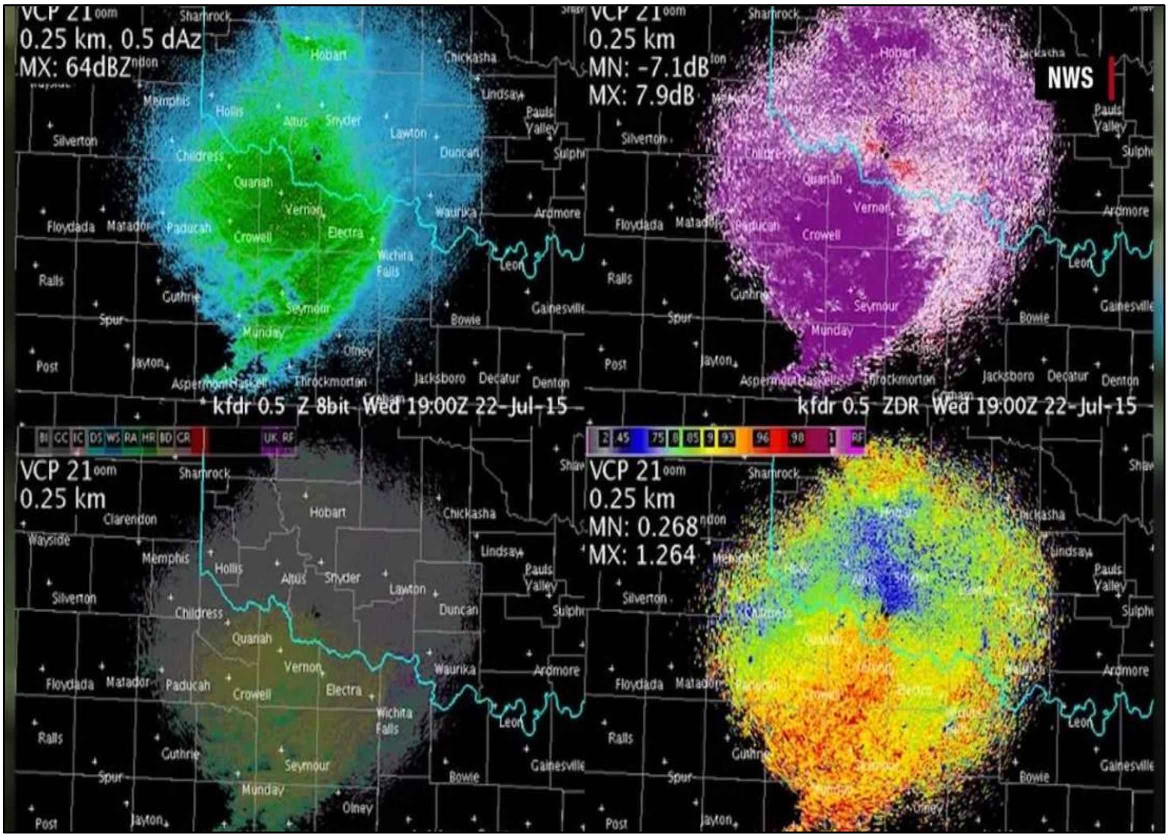
Remote sensing techniques used in entomology

Remote sensing techniques used in entomology include:

- Photography and videography from aircraft and from ground.
- Satellite- borne photography, multispectral scanning and thermal imaging.
- Ground-based and air-based RADAR (Radio detection and ranging).

RADAR

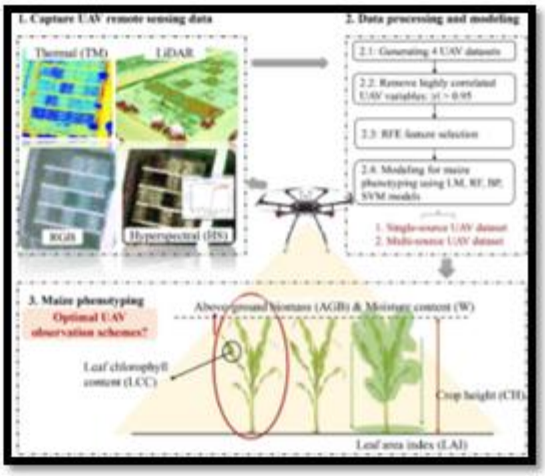
Radio detection and ranging (RADAR) perceives reflected radio waves from the surface of the object. Its operating principle is that it transmits radio waves and receives the same reflected by an object. The time interval between transmission and reception by the radar determines the exact position of the object. Radar has been used for studying long distance migration and flight behavior of wind borne / air borne insects. These radars use a wavelength of 3 to 10 cm. In case of small insects, millimeter radar is used. Typical maximum detection range is about 1.5 to 2.8 km for individual insects and several tenof kilometers for dense swarms. Flight behavior of locusts, grasshoppers and moths of various species of *Helicoverpa, Spodoptera etc*. has been studied through radar.



Radar and LiDAR entomology are emerging fields. Radars particularly polarimetric systems can be used effectively to detect and monitor insect pest population movements like migration. Radars can also be used to monitor high altitude migratory paths of insects. Doppler weather radars are able to detect and pinpoint area-wide population sources. They are also able to detect dense concentrations of airborne insects. Thus, radars and LiDARs contribute information on pest infestation density and population life stage. Integration of environmental condition to the above data will enable entomologist to predict the migration of insect pests. The portable harmonic radar system is a useful tool for effective detection of pest during both day and night. The harmonic radar system is also a useful tool to track the terrestrial insects. Even minute insects can be detected by a LiDAR system. Unlike radars, LiDARs can be used close to the ground for studying insects, including ecology and enthology.

Photography

Photography has been used extensively as a tool to obtain crop loss information. Panchromatic, colour infrared and black and white infrared films have also been utilized for photographing damage due to pests. In aerial photography the activity of insects is detected from the changes they produce in the appearance of plant foliage. Foliage may be changed if insects leave deposits on leaves or if they induce changes of leaf colour, shape or density as a direct or indirect result of feeding. Different types of damage can be differentiated in photographs. Defoliators like spruce budworm cause thinning of foliage and discolouration from green to yellow and yellow to red. This can be easily detected by aerial photographs. Similarly, sucking insects cause deformation of treetops, twigs and branches that can be seen through photographs. Photographic methods generally rely on the detection of plant stress or damage, which could be due to a variety of causes quite unrelated to insect activity. In such instances identification depends on the spot visual inspection. However, some insects like aphids produce honeydew on which sooty mould fungus grows. This fungus blackens the foliage, which is readily detectable by aerial photography.



Satellite -based multi-spectral scanning

These collect data in visible and infrared portions of the em spectrum. These are also called non-photographic techniques. These can form images over a much wider range of em wavelengths (0.4-14 pm) than the photographic method. These do not generate an instantaneous image of a whole scene.

Satellite based remote sensing has been used for two major purposes:

(i) The detection of changes in vegetation

(ii) The measurement of meteorological data.

An index called the ratio vegetation index, which is derived by dividing the near infrared reflectance by the red reflectance. It has been found to be a good indicator of -defoliation due to insect-pests in forest, areas. It is also helpful in exploring vegetation that could support locust breeding in normally desiccated areas. Because reflectance in the red region is inversely proportional to chlorophyll density and reflectance in the near infrared region is proportional to leaf density, a large index is indicative of high green leaf biomass.

Some applicative spectral readings

Measurements with multispectral scanner showed that groundnut with mite injury had a different spectral signature than groundnut infected with late leaf spot. Similarly spectral signatures of fields with low nematode population and high nematode population differed in visible and near IR region. It is also helpful in exploring vegetation that could support locust breeding in normally desiccated areas. Because reflectance in the red region is inversely proportional to chlorophyll density and reflectance in the near infrared region is proportional to leaf density, a large index is indicative of high green leaf biomass. Satellite remote sensing is an ideal tool to investigate the environmental factors controlling the pest development such as rainfall and air temperature. Flying moths of armyworm, *Spodopteraexempta* are brought together by winds associated with rainstorms. This subsequently leads to dense outbreaks of caterpillars.

Application of remote sensing technique in agriculture

- Crop production
- Drought resistance
- Soil resource
- Degraded land
- Land use/ land cover
- Water resource
- Flood / cyclone assessment
- Marine fisheries
- Weather forecasting
- Watershed management
- Forest coveGround water exploration
- Insect/pest management

Remote Sensing Applications Centre, Lucknow, Uttar Pradesh

Uttar Pradesh was the first and foremost state in the country to establish the first state Remote Sensing Applications Centre, Uttar Pradesh (RSAC-UP) in May, 1982 at Lucknow. RSAC-UP has been utilizing the geospatial technologies of satellite remote sensing, Image Processing, GIS, GPS, LiDAR, Bathymetry, Customized Software Development using AI, ML, DL & AL methods in conjunction with geophysical surveys, soil and water testing techniques for assessment, monitoring, utilization and management of various natural resources of the state with a view to achieve sustainable development.

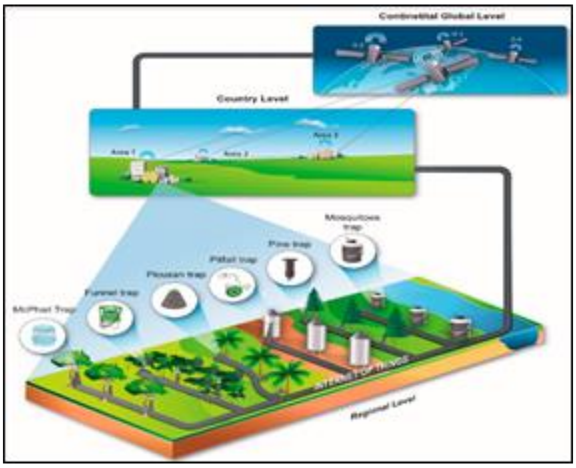
With the passage of time this RSAC-UP has diversified its domain from natural resource management to infrastructure mapping and monitoring, utility mapping, disaster management, Software development and is also involved in training, capacity building and vocational educational programme on geospatial technologies such as running M. Tech in "Remote Sensing and GIS". RSAC-UP is carrying out the work in crop area and production estimation of different crops, Space Based Information Support for Decentralized Planning, Wetland Inventory Assessment, Monitoring of Integrated watershed, Monitoring Vulnerability Assessment, desertification and Land Degradation, Assessment of Plantation outside forest areas, Water Sector Restructuring, Unauthorized Colony Mapping with the area of Development Authorities of U.P., Asset Mapping, Ground Water Targeting, Rural Urban planning including smart city and infrastructure planning.

Further the Centre is also working on pilot basis for the projects such as assessment of one district one crop, selection of cold storages for crop management, rejuvenation of alluvial rivers, disaster management, pilot studies on site suitability of suitable sites for rain water harvesting, fruit belt development, fodder crops and solid waste disposal etc. The Centre is also working on GIS mapping for schools, development and updation of satellite data and GIS based geoportal. Further, the Centre is imparting training on remote sensing applications to the officials of user departments and also to the faculty members and research scholars of universities.

Use of remote sensing for monitoring in IPM

Monitoring:

It requires estimation of change in insect distribution and abundance information about the insect, life history and the influence of important biotic and abiotic factor on pest population. IPM Development will develop inexpensive, reliable instrumentation for continual, remote, automated monitoring of insect pests, and their predators and parasitoids. This technology will enable pest managers to use networks of remote-access wireless sensors to monitor and predict insect activity in much the same way that meteorologists use networks of remote-access automated weather stations to monitor and predict weather conditions.



GIS (Geographical Information System)

A geographic information system (GIS) is a system that creates, manages, analyzes, and maps all types of data. GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a foundation for mapping and analysis that is used in science and almost every industry. GIS helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making.

Gis System

Decision Committee

A Geographic Information System (GIS) is a computer system that analyzes and displays geographically referenced information. It uses data that is attached to a unique location. By knowing the geographic location of farms using a specific fertilizer, GIS analysis of farm locations, stream locations, elevations, and rainfall will show which streams are likely to carry that fertilizer downstream. These are just a few examples of the many uses of GIS in earth sciences, biology, resource management, and many other fields.

GIS based decision support system

Geo-LIMIS (Geographically Encoded Locust Impact Minimization Information System) is a Decision Support System (DSS) developed on ARC/INFO.

- Access to historical records of locust sightings and associated environmental conditions.
- Rapid input and storage of accurately located sightings.
- Facilities to display and analyze locust events in the context of both current and antecedent environment conditions.
- Ability to compare the present spatio-temporal configuration of locust events, together with prior dynamics, to past analogue spatio-temporal sequences from previous plagues and recession periods.
- Interfacing between GIS and other analytical tools for modeling of locust development and migration.
- Analysis of the relationships between locust events and bio-climate.
- Analysis of daily weather data for bio-climatic modeling for breeding, upsurge and duration of life stage.

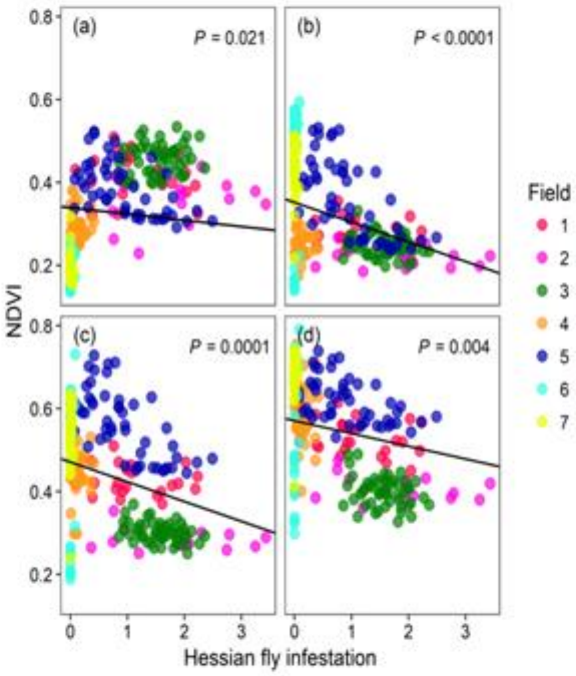
Field survey

Field survey has been an integral part of decision making during any integrated pest management program. Field survey can be done through drone photography and videography. Field survey helps in comparing and relating remote sensing obtained and the actual prevalent conditions, thus reducing the chances of errors.

Case study

i. **Remote sensing data to detect hessian fly infestation in commercial wheat fields by Ganesh P. Bhattara**

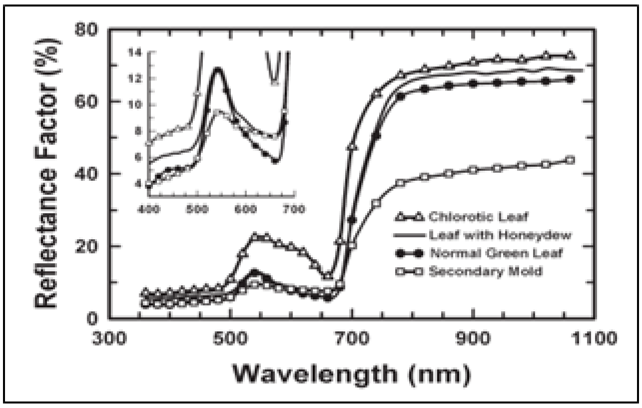
Multispectral satellite and aircraft data was used to evaluate the relationship between normalized difference vegetation index (NDVI) and Hessian fly (*Mayetiola destructor*) infestation. Visible and near-infrared data from each aerial platform to develop a series of NDVI maps for multiple fields. For both satellite and aircraft data, NDVI decreased with increasing pest infestation. These results indicate that remote sensing data can be used to assess the areas of poor growth and health of wheat plants due to Hessian fly infestation. Study suggests that remotely sensed data, including those from satellites orbiting >700km from the surface of Earth, can offer valuable information on the occurrence and severity of pest infestations in agricultural areas.



(ii) Application of remote sensing data for locust research and management

The above figure shows comparisons between hyperspectral reflectance factors of a normal green cotton leaf and a cotton leaf covered with honeydew produced by whiteflies (*Bemesiatabaci*), a leaf covered with a secondary mold *Aspergillus sp.* growing on the whitefly honeydew, and a chlorotic leaf without honeydew. Data were acquired with a Spectron SE590 spectroradiometer. Solar incidence angle was 45 degrees to the leaf surface and viewing angle was normal to leaf surface (Pinter, unpublished data).

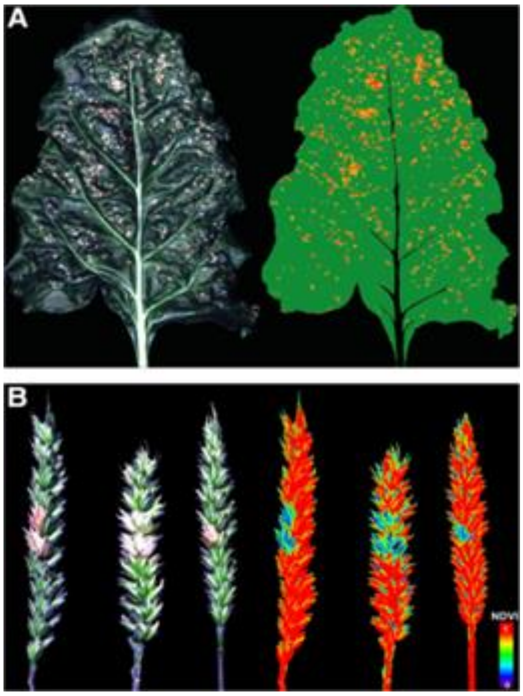
Most important applied sensors: -Advanced Very-High-Resolution Radiometer (AVHRR), Satellite Pour l' Observation de la Terre VEGETATION (SPOT-VGT). Moderate-Resolution Imaging Spectroradiometer (MODIS). As well as Landsat data focusing mainly on vegetation monitoring or land cover mapping. Application of geomorphological metrics as well as radar-based soil moisture data is comparably rare despite previous acknowledgement of their importance for locust outbreaks. Despite great advance and usage of available remote sensing resources, we identify several gaps and potential for future research to further improve the understanding and capacities of the use of remote sensing in supporting locust outbreak- research and management.



USDA, Agriculture research center, University of Nebraska By Paul J. Pinter

Sketch of locust interaction during gregarious phase. (Klein *et al.,* 2021)

(iii) Disease incidence prediction Pinter *et al.,* (1979) found that cotton plants whose roots were infected with the soil-borne fungus *P. omnivorum*and sugar beets infected with *Pythium apanidermatum*both displayed sunlit leaf temperatures that were 3 to 5°C warmer than adjacent healthy plants. The TIR was also useful for detecting root disease in red clover under irrigated conditions (Oliva *et al.,* 1994). Hyperspectral techniques are likely to provide some assistance, but coupling existing techniques with weather driven computer models of disease development will probably provide the best approach.



Conclusion:

Based on research findings on some crop pests and diseases, it can be used in agriculture insect pest management decisions, timely planning and getting different information in many specific areas such as - Survey of ecological conditions and forecasting insect pest outbreaks. Assessment of crop condition. Early detection of wild hosts and reducing the population build up, i.e., radish, winter peas, wild mustard etc. Early detection of insect pests, i.e., tarnish bugs in cotton fields.

Locating hot spots of pest infestation, i.e., spider mite infestation in cotton. Monitoring conditions favorable for pest outbreak and take management decisions in advance.Remote sensing of individual species of insects, i.e., locusts, moths and aphids etc. Survey of insect pests of crops and fruit trees, i.e., aphids in corn, scales and mealy bugs in citrus fields. Mapping geographical distribution of pests, along with GIS. As an aid in precision farming. Rainfall and outbreak of pests.

Survey of habitats of vectors of vertebrate pests. Remote sensing has been used to provide useful information on crop condition, detection of development of pest population in remote and inaccessible areas. Its aim is to bridge gaps in the existing systems securing a regular information flow about the areas affected by insect pests and diseases and other yield reducing factors on a nationwide basis. As remote sensing gives a synoptic view of the area in a non-destructive and noninvasive way, this technology could be effective and provide timely information on spatial variability of pest damage over a large area. Thus, remote sensing can guide scouting efforts and crop protection advisory in a more precise and effective manner. With the recent advancements in the communication, aviation and space technology, there is a lot of potential for application of remote sensing technology in the field of pest management.

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A STUDY ON PRICE VOLATILITY AND PREDICTED PROFIT IN RAISIN PRODUCTION FOR FINANCIAL SECURITY OF FARMERS IN DROUGHT PRONE REGION OF SANGLI DISTRICT

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Abstract:

The partially dried grapes are called raisins or Kismish. In state of Maharashtra, especially in drought region of Sangli district, the varieties, namely, Anushka, Clone, Manik Chaman, S.S.N., Thompson, and Super Sonaka are used to produce raisins. The period required to produce raisins after pruning is between 130 days to 190 days. Tasgaon drought tehsil is an important supplier of raisins in Maharashtra state. Drought Sangli district has favorable climate condition for the crop, water quality and soil fertility. Therefore, grapes are grown as a major crop in Sangli. Raisin has great demand at dry fruit, weddings and festival.The sale of good quality raisins ranges from Rs. 150 to Rs. 3000 per kg. After selling raisin in the market, the profit to the farmers should be satisfactory. In present research we study price variation and predicted profit of raisin using predictors such as variety of raisin (Variety), no of days required for raisin (Days), production area (Acre), production place (Tahsil), selling price (Rate), Sulfur furnace, expenditure, production(kg) of raisin through multiple regression model.

Keywords: Raisin, Price Volatility, Expenditure, Profit, Regression, Sulfur furnace, Production

Introduction:

Raisins or currants are semi-dried grapes. Currants are also called raisins in some places. Currants fall under the category of semi-dry fruits. After pruning, the grapes are formed and become bigger. The grapes are harvested after they have matured, then the grapes are keptin sheds to dry and the whole process takes 130 days to 190 days to form raisins. During this period, diseases also occur on the grapes, to protect grapes from such type of diseases, many expensive drugs and chemicals are sprayed on the grapes. Also shed costs a lot to dry those grapes. After the currants are prepared, they are given a Sulfur furnace, which also costs a lot of money to the farmers. After spending all this, currants are produced and then after selling them, the farmers get their compensation.

Tasgaon- Sangli is famous in Maharashtra for delectable raisins. The Maharashtra stateranks first in terms of production of grapes and annually exports more than 2.01 lakh tonnes ofgrapes. The approximate annual production of raisins in Sangli is 2.15 lakh tonnes of which 35 – 45 percent is exported. A big auction market of raisins was started in 1994 in Tasgaon which now has more than 110 trading centres and 65 – 70 cold storage warehouses.

M.G. Kerutagi *et al.* (2018) carried out economic analysis for production and marketingof raisins in Vijayapura District. Dr. J. G. Mulani (2018) studied raisins marketing in Sangli agriculture produce market committee and discussed about prices of raisin in Sangli APMC.

M.S. Ladaniya *et al.* (2005) recorded negative correlation co-efficient in monthly prices and arrivals at national level and major markets in Maharashtra. Mrs. Dhanashri Y Jadhav *et al.* (2021) discussed problems and prospectus of raisin production in Sangli district of Maharashtra. The main purpose of this study is to fit multiple linear regression on profit of raisin.

Methods and Materials:

The present study is based on the primary data. The primary data were collected from farmers of five tahasils of Sangli district through questionnaire. Out of 216 respondents, 126, 37, 17,20, 16 from Juth, Tasgaon, Atpadi, Kavathe Mankhal and Miraj are respectively. TheStatistical technique called as multiple linear regression used to predict the profit of raisin. Thedata analysis has been done in SPSS.

Statistical analysis:

For this study, the response variable is profit and predictors are variety of raisin (Variety), no of days required for raisin (Days), production area (Acre), production place (Tahsil), selling price (Rate), Sulfur furnace, expenditure, production (kg) of raisin. In this predictors, variety of raisin (Variety), production place (Tahsil) and Sulfur furnace are categorical variable. To do multiple linear regression, we need to code this categorical variable. Thus, the variable coded variety of raisin (Variety) as Anushka (1), Clone (2), Manik Chaman (3), SSN (4), Super Sonaka (5) and Thompson (6). The variable Tahsil coded as Juth (1), Tasgaon (2), Atpadi (3),Kavathe Mankhal (4) and Miraj (5). The variable

Sulfur furnace coded as, No (0) and Yes (1).The multiple linear regression model that there is linear relationship between one dependent variable and two or more independent variables. The general form of multiple linear regressiondescribed as follows:

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + - - - + \beta_k x_k + e_i$$

Where,: Value of i^{th} observation for the dependent variable.

: Value of the j^{th} coefficient, j = 1, 2, …., k

: j^{th} independent variable,, j = 1, 2, …., k

e_i: Error in the observation value for the i^{th} case.

Hypothesis for overall F test:

$$H0: \beta_1 = \beta_2 = --- = \beta_8 = 0$$

H1: At least one β_i^s are different from zero.

In this research study, we want to establish the relationship between profit from raisin and variety of raisin (Variety), no of days required for raisin (Days), production area (Acre), production place (Tahsil), selling price (Rate), Sulfur furnace, expenditure, production (kg) of raisin. Model summary (Table 1) provides the values of R, R-square, Adjusted R-square andStd. Error of the Estimate for the fitted model. The value of R-square 0.981, indicates that 98.1% variation in profit of raisin explained by independent variables, namely, Rate, Days, Variety, Acre, Sulfur furnace, Tahsil, Expenditure, production(kg).

Table 1: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.990[a]	.981	.980	87374.025
a. Predictors: (Constant), Rate, Days, Variety, Acre, Sulfur furnace, Tahsil., Expenditure, production(kg)				

The ANOVA Table 2 contains Sum of Squares (SS), Degrees of Freedom (df), Mean Square (MS), F-test statistic and P-value (Sig.). The value of F statistic is 1332.197. The p-value for F statistic is 0.000 which is less than 0.01 (level of significance). Hence, we reject the null hypothesis at 1% level of significance and conclude that least one β_i^s are different from zero. It indicates that fit of model is better. (i.e. The model is useful for prediction of profit).

Table 2: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	81362299481300.830	8	10170287435162.604	1332.197	.000[b]
	Residual	1580283584949.175	207	7634220217.146		
	Total	82942583066250.000	215			
a. Dependent Variable: Profit						
b. Predictors: (Constant), Rate, Days, Variety, Acre, Sulfur furnace, Tahsil, Expenditure, production(kg)						

The coefficient Table 3, gives the value of regression coefficients for each predictor with their standard error. It also includes t test statistic and p-value (Sig.) for each predictor.

Table 3: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-979903.343	113445.101		-8.638	.000
	Tehsil	2090.689	4806.082	.004	.435	.664
	Variety	-1182.593	3836.424	-.003	-.308	.758
	Acre	2669.047	5939.418	.007	.449	.654
	Production(kg)	168.961	2.746	1.051	61.527	.000
	Expenditure	-.876	.084	-.165	-10.408	.000
	Sulfur furnace	20061.386	14817.861	.013	1.354	.177
	Days	186.903	669.729	.003	.279	.780
	Rate	5432.903	250.387	.221	21.698	.000
a. Dependent Variable: Profit						

Result and Discussions:

The general form of the equation to predict profit of raisin is:

$\hat{Profit}$ = *-979903.343 + 2090.689Tehsil -1182.593Variety + 2669.047Acre + 168.961 Production (kg)*

-.876Expenditure + 20061.386Sulfur furnace + 186.903Days + 5432.903Rate

The Unstandardized coefficients indicate how much the dependent variable varies with an independent variable when all other independent variables are held constant.

The unstandardized coefficient of Tahsil is 2090.689. This indicates that for each one unit increase in Tahsil, there is increase in profit of Rs. 2090.689. (e.g. Here we coded the tahsil variable as: Jath (1), Tasgaon (2), Atpadi (3), Kavathe Mahankal (4) and Miraj (5). Thus, the place of production (Tahsil) changed Jath to tasgaon, the profit increases by Rs.2090.689 or the place of production (Tahsil) changed Jath to Atpadi, the profit increases by Rs.4181.378 when other variables held constant).

The unstandardized coefficient of Acre is 2669.047. This indicates that for each one unit increase in Acre, there is increase in profit of Rs. 2669.047 when other variables held constant.

The statistical significance of each predictor is tested by using t-test statistic. The predictor which has p-value of t test statistic is less than or equal to 0.01 are statistically different from zero. However, those predictors p-value of t test statistic is greater than 0.01 arestatistically not different from zero.

Illustration:

A farmer belongs to Kavathe Mankhal has 3 acres of manik chaman. He produced 10000 kg of raisin and it cost him Rs. 500000. He was given a sulfur furnace for raisin, costing him 155 days to produce raisin and he got rate Rs.180 for per kg then the predicted profit of raisin is Rs.12,6,379.

i.e. $\hat{Profit}$ = *-979903.343 + 2090.689(1) -1182.593(3) + 2669.047(3) + 168.961(8000) -.876(400000)*

+ 20061.386(1) + 186.903(155) + 5432.903(180)

$\hat{Profit}$ **=** 12, 6, 379 Rupees.

Conclusions:

Farmers spend money on crops without any thought of profit and this can lead to huge losses. To overcome this loss of farmer, we fitted multiple linear regression model to predict the profitof Raisin. So, farmers can use this model, to spend less money on crop and earn more profit. Infuture, Optimization techniques are used in the research and researcher will maximize the raisin profit.

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NANO UREA: A REVOLUTIONARY TOOL FOR PRECISION AGRICULTURE

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Introduction:

Precision agriculture, an innovative farming technique, has transformed crop cultivation by incorporating technology, data analysis, and modern agricultural methods. (He and Rajasekaran, 2019; Bhattacharyay *et al.* 2020). This approach focuses on optimizing resources, improving productivity, and minimizing the environmental footprint. A key element of this transformation is the strategic use of fertilizers, ensuring crops receive the vital nutrients required for peak growth and productivity. Fertilizers have long been acknowledged as a fundamental element of modern agriculture, playing a crucial role in boosting crop production and ensuring global food security (Khan *et al.* 2020; Sairam *et al.* 2023a; Sahoo *et al.* 2023). By delivering critical nutrients like nitrogen, phosphorus, and potassium, fertilizers are vital for plant growth, development, and overall health. Yet, traditional fertilizer application has frequently caused problems like nutrient runoff, soil degradation, and inefficient nutrient uptake by plants (Sairam *et al.,* 2023b). This is where precision agriculture becomes relevant, delivering a cutting-edge solution to improve fertilizer efficiency in a sustainable and targeted fashion. In the last few years, nanotechnology has emerged as a revolutionary field with the ability to transform diverse industries, including agriculture (Raliya and Tarafdar, 2013). Nanotechnology focuses on manipulating materials at the nanoscale, ranging from 1 to 100 nanometers. Its application in agriculture offers the potential to develop innovative tools and solutions to tackle enduring problems faced by farmers and the agricultural sector.

Nano urea, a groundbreaking fertilizer developed through nanotechnology, is essential for providing plants with adequate nitrogen. This sustainable choice has become pivotal for farmers aiming to boost crop yields while adopting advanced agricultural practices. Even though traditional urea is efficient, it can lead to environmental concerns, especially with excessive use. Its high water solubility often results in leaching, de-nitrification, and losses through volatilization. Unlike conventional fertilizers, liquid nano urea facilitates effective nitrogen absorption and penetration into leaves when applied as a foliar spray. This approach ensures that nutrients reach the required parts of the plant. Moreover, it provides nutrients in a controlled release, minimizing waste and helping to prevent environmental pollution.

Chemical composition of nano urea

With 46% nitrogen, packed urea delivers around 20 kg of nitrogen in a 45 kg bag. In comparison, nano urea, which comes in 500 ml bottles, contains only 4% nitrogen, or about 20 grams. IFFCO introduced the first nano urea, which offers nitrogen in granules 100,000 times finer than a sheet of paper. At the nanoscale, which is about one billionth of a meter, materials have distinct properties compared to those at larger scales.

Application procedure

Prepare a solution of 2 to 4 ml of nano urea in one liter of water and spray it onto the crop leaves during active growth stages. To maximize results, apply two foliar sprays: the first at the active tillering or branching stage (30-35 days after transplanting) and the second 20-25 days after the first spray or before the crop flowers.

Note: Do not reduce the nitrogen supplied by DAP or complex fertilizers during the basal stage. Instead, decrease the top-dressed urea applied in 2-3 splits. The application frequency of nano urea can be adjusted based on the crop's nitrogen needs.

Application instructions

1. Shake the bottle thoroughly before use.
2. Use flat fan or cut nozzles for applying the spray to the leaves.
3. Apply the spray in the morning or evening and avoid spraying during dew.
4. If rain falls within 12 hours after application, a repeat spray is advised.

5. Nano urea mixes well with biostimulants, 100% water-soluble fertilizers, and agrochemicals. Always perform a jar test before mixing and spraying to ensure compatibility.

Advantages of nano urea

- **Enhanced efficiency in nutrient use:** Nano urea enhances nutrient availability to crops by more than 80%, resulting in a major improvement in Nutrient Use Efficiency (NUE). This increased efficiency is vital for sustainable farming practices, ensuring better resource use.
- **Environmental impact mitigation:** Nano urea addresses environmental issues by significantly reducing nutrient loss from fields. Unlike traditional fertilizers, which can lead to leaching and gaseous emissions that harm the environment, nano urea's-controlled release mechanism effectively mitigates these problems.
- **4 R nutrient approach:** Nano urea plays a crucial role in the 4 R nutrient stewardship, promoting precision and sustainable chemical use. This strategy focuses on applying nutrients at the Right source, Right rate, Right time, and Right place to maximize resource efficiency.
- **Sustainable technology:** Nano urea's industrial production process is both energy-efficient and resource-saving, adhering to clean and green technology principles. This sustainability factor enhances its attractiveness as an environmentally responsible agricultural input.
- **Boosting smart agriculture:** By providing a targeted and efficient solution for plant nutrients, nano urea embodies the principles of smart agriculture. Its application precision aids in the advancement of modern farming methods.
- **Effective nitrogen and phosphorus source:** Nano fertilizer delivers an effective supply of nitrogen (N) and phosphorus (P2O5) to various crops. It addresses nutrient deficiencies in growing crops and encourages robust plant development.
- **Nano DAP composition:** The nano DAP formulation, with particles less than 100 nanometers in size, boasts a higher surface area relative to its volume. This property enhances its ability to penetrate seeds and plant openings, leading to improved nutrient absorption.
- **Crop yield and quality enhancement:** Utilizing nano DAP as a seed treatment or foliar application at crucial growth stages increases the availability of nutrients to crops. This results in improved crop yields, stronger seed vigor, more chlorophyll

production, and enhanced photosynthetic efficiency. Additionally, the quality of the harvested produce, including protein and nutrient content, is positively impacted.

- **Reduced chemical fertilizer usage:** The application of nano technology can significantly reduce the need for conventional DAP fertilizers. Its targeted approach during key growth periods lowers the requirement for bulk fertilizers, promoting a more sustainable agricultural practice.
- **Efficient storage and transport:** The use of Nano fertilizers, which require smaller amounts compared to bulky phosphatic fertilizers, facilitates easier storage and transportation. This practicality aids farmers in managing and moving Nano DAP bottles more conveniently.

Challenges associated with nano urea

- **Research gaps and uncertainty:** The benefits of nano urea are promising, but there is ongoing uncertainty about its actual impact on crop yields. Scientists advocate for further research to thoroughly evaluate its effects.
- **Potential environmental risks:** The use of nano fertilizers, including Nano Urea, raises concerns about their potential adverse effects on both human health and the environment. The nanoparticle concentration is particularly important, as higher concentrations might increase risks.
- **Technology adoption challenges:** The integration of Nano Urea into farming practices involves a learning curve as farmers adjust to new technology. Proper knowledge of application techniques and usage guidelines is important for effective results.
- **Financial considerations:** Although Nano Urea can lower transportation and storage expenses, the initial costs of adoption and potential price fluctuations could affect farmers' budgets. It is important to weigh the benefits against economic feasibility.
- **Precision in application**: Effective use of liquid Nano Urea requires careful attention to detail. Farmers should follow specific guidelines regarding dilution ratios, spraying practices, and timing to ensure the best results.

Future prospects of nano urea

Nano urea, an advanced breakthrough in precision agriculture, offers great potential for the future of sustainable farming. By delivering nutrients more efficiently at the nanoscale, it can enhance crop yields while reducing the environmental footprint of traditional fertilizers. The precise application of nano urea ensures that crops receive the exact amount of nutrients needed, minimizing wastage and reducing the risk of nitrogen leaching into water bodies, which can lead to pollution and eutrophication.

Looking ahead, the widespread adoption of nano urea could revolutionize agriculture by promoting higher productivity on less land, thereby supporting global food security. Additionally, it could contribute to the reduction of greenhouse gas emissions from agricultural practices, as less fertilizer would be required to achieve optimal crop growth. However, further research is needed to fully understand the long-term impacts of nano urea on soil health, plant physiology, and the broader ecosystem. As the technology advances, integrating nano urea with precision farming tools such as drones, sensors, and AI-driven analytics will be crucial in optimizing its benefits. Ultimately, nano urea represents a significant step toward more sustainable, efficient, and environmentally friendly agricultural practices.

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MICRO IRRIGATION: ENHANCING WATER USE EFFICIENCY IN PRECISION AGRICULTURE

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Introduction:

The agricultural sector globally confronts significant challenges related to water scarcity and the efficient management of water resources. Irrigation, which involves the artificial supply of water to satisfy crop requirements, is vital for maintaining agricultural productivity and addressing the increasing demand for food (Deng *et al.,* 2006; Maitra & Pine, 2020). Nevertheless, conventional irrigation practices are often plagued by inefficiencies, which lead to overconsumption of water, wasted energy, and detrimental environmental effects. In recent years, there has been a notable increase in the development and use of micro irrigation techniques aimed at enhancing water efficiency and promoting sustainable water management in agriculture (Santosh & Maitra, 2021). Micro irrigation entails the accurate delivery of water in precise quantities, at optimal times, and at specific locations, customized to meet the individual needs of plants and soil conditions. This method signifies a fundamental change from conventional uniform irrigation techniques to targeted, site-specific water application (Santosh & Maitra, 2022). Improvements in micro irrigation techniques have been largely driven by technological advances, including the use of sensors, automation, remote sensing, data analytics, and the Internet of Things (IoT) (Kamienski *et al.,* 2019). These technological advancements empower farmers and water managers to control irrigation systems with increased precision and efficiency. By combining real-time data, weather conditions, soil moisture measurements, and plant hydration needs, micro irrigation systems deliver a dynamic and adaptive water management solution.

Micro-irrigation in farming: Developments and future potential

Precision water-management technologies, such as micro-irrigation methods (including sprinkler, surface drip, and subsurface drip), assist cultivators by conserving irrigation water and lowering production costs through more efficient use of fertilizers, reduced labor expenses, and decreased overall agricultural inputs (Madhavan, 2020;

Narayanamoorthy, 2006). Compared to conventional flood irrigation systems, micro-irrigation methods can save between 35% and 65% of water and lead to notable improvements in crop yields and farmer earnings (ICFA, 2017; Jat *et al.,* 2019a,b; Sidhu *et al.,* 2019). The benefits of micro-irrigation in substantially improving water use efficiency have been clearly established through numerous studies (Narayanamoorthy, 2003; Palanisami *et al.,* 2011; Rajkhowa *et al.,* 2015; Rajput and Patel, 2012; Soman, 2020; Soman *et al.,* 2018). Despite substantial benefits and government initiatives, the use of micro-irrigation in South Asian countries lags far behind its adoption in developed countries such as Russia, the USA, Brazil, Israel, Spain, and China (Fig. 2; ICFA, 2017). Among South Asian countries, India has the highest acreage under micro-irrigation, which has been increasing consistently. Since 2005, the area equipped with micro-irrigation systems has experienced a compound annual growth rate (CAGR) of 9.6% (Anonymous, 2016). Of the total area utilizing micro-irrigation, sprinkler systems represent 56%, while drip irrigation systems make up 44%. Drip irrigation is growing more rapidly, with a compound annual growth rate (CAGR) of 9.85% from 2012 to 2015, compared to the 6.60% CAGR for sprinkler irrigation during the same period (Priyan & Panchal, 2017). Currently, micro-irrigation covers 7.73 million hectares in India, with a potential expansion area exceeding 42 million hectares (ICFA, 2017).

Advantages of micro irrigation

- It saves water and produces higher yield.
- Ideal for all type of soils
- Farm operational cost saving
- Use of recycled, waste and saline water.
- Potential improved distribution uniformity of water and chemicals.
- An easy way to take fertigation which is a method of delivering fertilizer and water to plants and crops via an irrigation system.

Disadvantages of micro irrigation

- The installation process is time consuming.
- Higher initial investment.
- Clogging of emitters.
- Plastic tubes affect soil fertility.
- Sun heat affects tubes; they might break as a result of excessive heat production.

Classification of micro irrigation system

Micro irrigation systems are generally categorized into two main types: (1) Drip irrigation systems and (2) Sprinkler irrigation systems.

Drip irrigation systems

Drip irrigation is a type of micro-irrigation system, alongside other methods such as sprinkler, micro-sprinkler, and mini sprinkler. Drip irrigation involves the precise and controlled delivery of water and nutrients to plants at low pressure, through a network of pipes and emitters or drippers, over time and at short intervals. As of 2013, drip irrigation was implemented across approximately 2.85 million hectares in India (NCPAH, 2013). Maharashtra led the states in adopting drip irrigation, covering 0.83 million hectares, followed by Andhra Pradesh with 0.73 million hectares. Gujarat and Karnataka followed with 0.35 and 0.33 million hectares, respectively.

Table 1: Crops grown under drip irrigation

Crop Group	Crops
Orchard and fruits Banana	Banana, Grapes, Papaya, Pomegranate, Oranges and Lemons, Mango, Custard apple, Aonla, Sapota, Guava, Litchi, Melons, Coconut, Arecanut, Cashew nut, etc.
Vegetable	Tomato, Chillies, Capsicum, Cabbage, Cauliflower, Onion, Bhendi, Gourd crops, Peas, etc
Cash crops	Sugarcane, Cotton, Turmeric, Garlic, Cloves, etc
Flowers	Rose, Carnation, Gerbera, Anthurium, Orchids, Jasmines, Dahlia, Marigold, etc
Oilseeds	Sunflower, Oil palm, Groundnut, etc.

It is estimated that 45 million hectares in the country have potential for micro-irrigation, with drip irrigation projected to cover approximately 15 million hectares of this area. The estimated coverage of drip irrigation by 2013 is around 20 percent. Unlike surface irrigation, which involves open channels that result in evaporation, percolation, and seepage losses, drip irrigation uses a pipe network to deliver water directly from the source to the plant's root zone. In surface irrigation, the entire land area is irrigated, whereas drip irrigation targets the specific crops or plants. Drip irrigation can achieve an efficiency rate of up to 95 percent, compared to only 50 percent with surface irrigation. This system supports the cultivation of a wide range of crops, including horticultural crops, cash crops, orchards, flowers, and oilseeds (Table 1).

Advantages of drip irrigation

1. **Water saving:** In this system, water is delivered directly to the root zone, minimizing waste. Drip irrigation has water losses of only 2-3%, whereas sprinkler irrigation has 10-20% water loss.
2. **Energy conservation**: Drip irrigation reduces power consumption by operating at much lower pressures than other irrigation methods.
3. **Fertilizer efficiency**: Direct application of fertilizers and chemicals to the root zone with drip irrigation can lower the amount and cost of these inputs by 25-30% compared to traditional irrigation systems.
4. **Labor savings**: Significant labor savings of 60-90% can be achieved with drip irrigation, as it eliminates the need for constructing borders, bunds, and other labor-intensive features required in conventional irrigation.
5. **Lower quality water utilization**: A well-managed drip irrigation system can utilize lower quality water more effectively than sprinkler or flood irrigation. Continuous water application prevents the root zone from drying out and helps move salt away from the roots, thereby leaching accumulated salts to the edges of the wetted soil mass. This process allows drip irrigation to manage higher salt concentrations more efficiently.
6. **Compatibility with cultural practices**: Drip irrigation allows for the continuation of most cultural practices during its operation. While the immediate area around the plant roots is kept wet, the spaces between rows or ridges remain dry, facilitating harvesting and enabling inter-cultivation.
7. **Application in hilly and problematic soils**: Drip irrigation is suitable for hilly terrains that are not economically feasible to level and for soils with issues like slow percolation rates. It allows the effective use of such challenging land and soil conditions.

8. **Reduced weed growth**: Since drip irrigation delivers moisture directly to the plant's root zone, the surrounding soil remains dry. This localized watering minimizes the conditions favorable for weed seed germination and growth, thereby reducing weed proliferation.
9. **Reduced soil erosion**: By delivering water and nutrients directly to the root zone at lower pressures, drip irrigation reduces soil erosion and makes field operations easier.
10. **Boost in yield and plant health**: Drip irrigation helps young trees grow faster by providing a steady supply of water without disrupting the soil structure. This approach ensures optimal moisture levels and prevents the physiological water stress often seen with conventional irrigation.
11. **Enhanced quality of plant products**: The slow, regular, and uniform application of water and nutrients through drip irrigation leads to improved quality of plant products by ensuring consistent soil moisture.
12. **Decreased pest and disease risks**: Drip irrigation reduces soil surface wetting and lowers humidity, which minimizes the risk of pest infestations and fungal diseases.

Limitations of drip irrigation system

1. **High initial investment**: The high upfront cost of installing a drip irrigation system can be offset by the benefits of increased irrigated area and higher yields, alongside reduced operational costs.
2. **Clogging issues**: Drip irrigation systems are prone to blockages caused by sand, silt, organic matter, algae, bacterial slime, nutrient precipitates, undissolved nutrients, colloidal or dissolved iron, and calcium carbonate. Effective filtration, using self-cleaning filters and sand or gravel filters, can address and prevent clogging problems.
3. **Root development concerns**: Drip irrigation can lead to roots concentrating in the wet areas around the drippers. If the wetted area is too limited, it can make plants more susceptible to being uprooted by strong winds. Proper placement of drippers can mitigate this risk. Additionally, a confined root system means plants become highly dependent on regular water supply; if the system fails, plants may experience significant stress compared to those irrigated by conventional methods. Thus, a reliable water source is crucial.

Components of drip irrigation

The components of the portable sprinkler system are illustrated in Figure 3. Major components of Drip Irrigation System are:-

(A) Pump

(B) Head control unit

(1) By-Pass Assembly

(2) Non Return Valve/Check Valve

(3) Air Release cum Vacuum Breaker Valve

- Air Release Valve
- Vacuum Breaker Valve

(4) Filtration Unit

(5) Fertigation Unit

(6) Main Valve/Throttle Valve

(7) Pressure Gauge

(8) Flow Meter/ Water Meter

(C) Water carrier system

(1) Mainlines

(2) Sub-mains

(3) Control Valve

(4) Flush Valve

(D) Water distribution system

(1) 12/16 MM Laterals

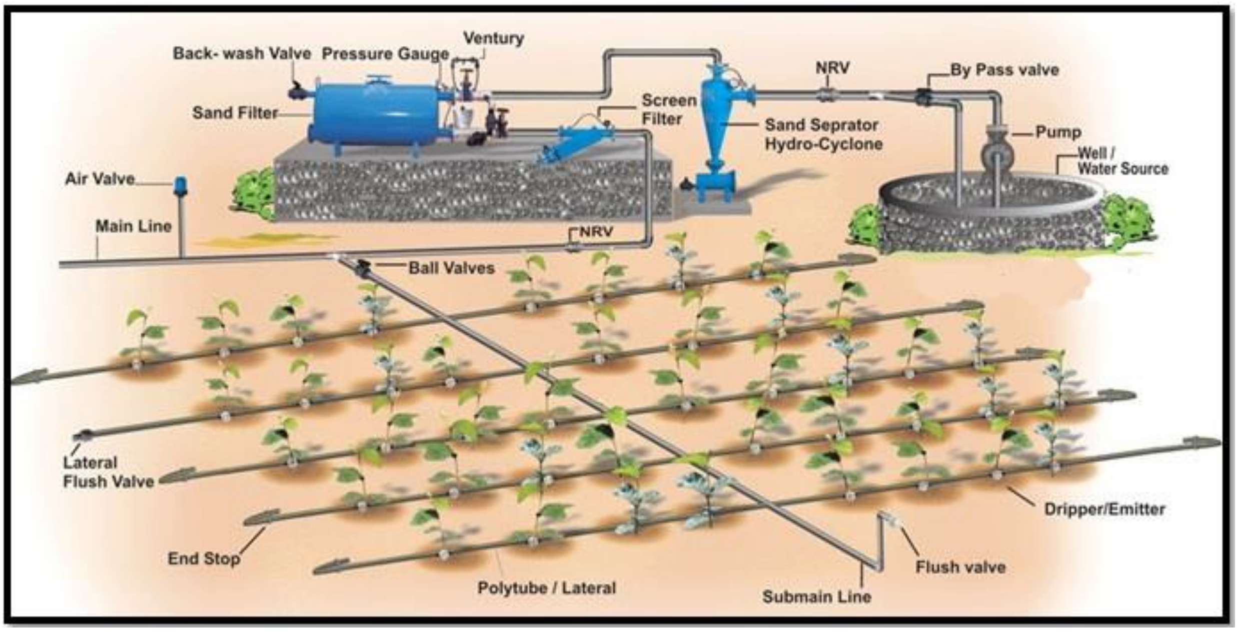
(2) Drippers (Emitters)

(3) Built-in-Drippers Tube

(4) Poly Fittings

- Grommets
- Start Connector (Take Off)
- Spaghetti (Extension Tube)
- Micro Tube
- Straight Connector (Nipple) /Barbed Connector
- Barbed Tee-
- Barbed Reducer
- Barbed Elbow

- End Closure
- Tubing Tap, etc.



Layout of drip irrigation system

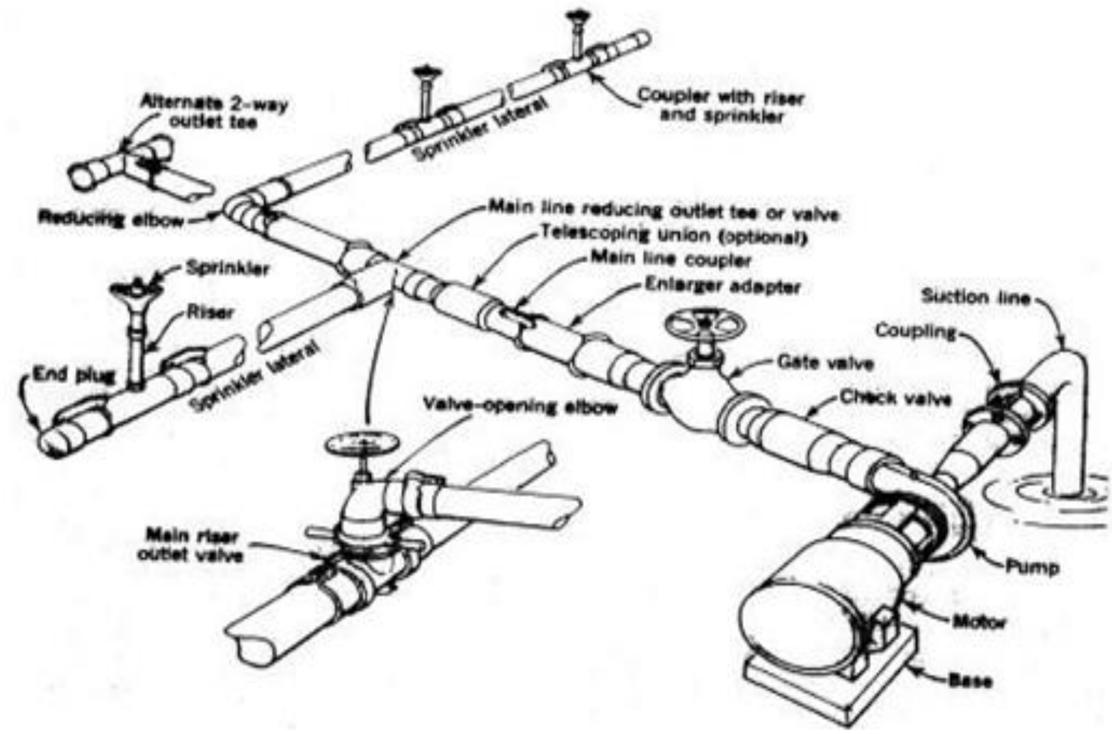
Sprinkler irrigation system

In sprinkler irrigation, water is cast into the air and permitted to gently fall onto the soil surface, replicating the natural occurrence of rainfall. This spraying effect is created by passing water through small nozzles or orifices under pressure, typically supplied by a pump. By carefully selecting the size of the nozzles, the pressure, and the arrangement of the sprinklers, water can be distributed evenly to the crop root zone at a rate that matches the soil's infiltration capacity.

Advantages of sprinkler irrigation system

1. Effective for all soil types except heavy clay.
2. Ideal for crops with high plant densities per unit area.
3. Particularly suitable for oilseeds, cereals, and vegetables.
4. **Water efficiency**: Allows precise control over water application, making it easy to provide light, frequent irrigation and achieve higher water use efficiency.
5. **Increased yields**: Can lead to higher crop yields.
6. **Mobility**: The system can be moved as needed and is suitable for uneven terrain.
7. **Land Use**: Saves land by eliminating the need for bunds and other structures.
8. **Elevation**: Can irrigate areas situated higher than the water source.
9. **Fertilizer application**: Facilitates the use of soluble fertilizers and chemicals.

10. **Clogging**: Reduced risk of nozzle clogging from sediment-laden water.



Components of Sprinkler Irrigation System

Constraints in application sprinkler irrigation

1. **Uneven distribution**: Water distribution can be inconsistent, especially in windy conditions.
2. **Evaporation losses**: High temperatures can lead to significant evaporation losses during operation.
3. **Soil limitations**: Not suitable for highly impermeable soils.
4. **High initial investment**: The upfront cost of installing a sprinkler system is substantial.
5. **Design complexity**: Requires careful and precise design for optimal performance.
6. **Lack of best practices**: Absence of standardized practices and guidelines.
7. **Awareness deficit**: Limited knowledge among users about sprinkler irrigation benefits and management.
8. **Resource conservation**: Insufficient emphasis on the need to conserve natural resources.
9. **High pressure requirement**: Sprinkler systems need high water pressure (>2.5 kg/cm^2) to operate effectively.
10. **Wind issues**: Irrigation can be challenging during windy conditions.

The components of the portable sprinkler system are illustrated in Figure 3 (Source: Schwab *et al.* (1993), pp. 427). A sprinkler system usually consists of the following components

- A pump unit
- Tubings- main/submains and laterals
- Couplers
- Sprinker head
- Other accessories such as valves, bends, plugs and risers.

In choosing a sprinkler system, consider the following physical parameters:

1. The types of crops being cultivated.
2. The size and configuration (in acres) of the field.
3. The field's topographical characteristics.
4. The time and effort required for system operation.

Conclusion:

In this chapter, we explored the importance of micro irrigation, specifically drip and sprinkler techniques, in enhancing water use efficiency within precision agriculture. Both methods allow for precise water delivery directly to the root zones of plants, reducing waste and ensuring optimal moisture levels for crop growth. Drip irrigation excels in conserving water by minimizing evaporation and runoff, while sprinkler systems offer flexibility for different crop types and field conditions.

Integrating these techniques with precision agriculture technologies, such as soil moisture sensors and automated controls, further optimizes water use, leading to higher yields and reduced environmental impact. As agriculture faces increasing challenges from climate change and water scarcity, the adoption of drip and sprinkler irrigation systems within precision farming is essential for achieving sustainable and efficient food production. These techniques represent a vital step toward securing the future of agriculture in a resource-constrained world.

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EVOLUTION OF AGRICULTURE: FROM TRADITION TO MODERNITY

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Abstract:

Precision farming is an innovative technique combining cutting-edge technologies with traditional farming strategies. This method makes use of facts-driven technology, which include GPS, IoT, and faraway sensing, to maximise crop yield, cut waste, and assure sustainable useful resource use. Precision agriculture comprehensively responds to current agricultural issues through bridging the space among modern technology and time-examined farming techniques. The synergy among technology and lifestyle is tested in this abstract, which emphasizes how precision agriculture may additionally increase output whilst protecting farming groups' cultural legacy.

Introduction:

For heaps of years, agriculture has shaped economies, cultures, and civilizations, serving because the cornerstone of human civilization. The necessity to feed a growing global populace has pushed main evolution in farming practices since the early days of crop cultivation and animal husbandry. The farming communities' cultural legacy has been safeguarded, biodiversity has been included, and food protection has been assured by means of the traditional practices that have been surpassed down through the years. But new methods are required to meet the problems dealing with present day agriculture, which include population expansion, resource scarcity, climate trade, and the need for improved manufacturing. A ground-breaking strategy for overcoming these boundaries is precision agriculture, which combines modern technology with traditional farming strategies. It is an stylish synthesis of traditional information and present day generation that provides a route to profitable, efficient, and sustainable farming.

The evolution of agriculture: From tradition to modernity

There had been vital turning points along the way from guide labor to mechanized in agriculture. The shift from nomadic hunter-gatherer organizations to everlasting agricultural settlements hooked up the foundation for the improvement of civilizations.

Farmers were practicing crop rotation, irrigation, and selective breeding for millennia to growth yields and hold their groups. These age-old methods, which have their roots in environmental attention and neighborhood expertise, have fashioned the foundation of agriculture.

Agriculture noticed a dramatic transformation because of the Industrial Revolution. The introduction of chemical pesticides and fertilizers enhanced output, while mechanization reduced the want for guide labor. Through the advent of excessive-yield crop types and modern farming strategies, the Green Revolution of the mid-twentieth century similarly modified agriculture, especially in terrible nations.

Technological tools in precision agriculture

Several technological advancements have pushed the growth of precision agriculture:

- Global Positioning System (GPS): Farmers can map their fields with extreme precision thanks to GPS technology. This makes it feasible to plant, fertilize, and harvest plants exactly, minimizing overlap and making sure that every part of the sphere receives the right care.
- Remote sensing: Real-time records on crop health, soil situations, and environmental factors are supplied by means of satellite pictures and drones fitted with cameras and sensors. With the useful resource of this information, farmers are better capable of hit upon problems early on and take suitable motion, which includes pest infestations, water pressure, and nutrient deficits.
- Internet of Things (IoT): IoT devices continuously reveal field situations and transmit information to a principal gadget. Examples of IoT gadgets are climate stations and soil moisture sensors. Weather styles are anticipated, irrigation plans are optimized, and general farm management is more desirable with the aid of the analysis of this data.
- Big data and analytics: To make feel of the sizable volumes of facts produced by using precision agriculture units, sophisticated analytics are needed. This fact is analyzed with the aid of AI structures and system mastering algorithms to provide beneficial insights that may be used to forecast agricultural yields, maximize useful resource usage, and see patterns that can have an effect on upcoming developing seasons.

- Automation and robotics: Robotics also have become more standard in precision agriculture and this includes self driven tractors, drones and robots. The efficiency of these gadgets in planting, weeding and harvesting and so on means reducing the labor costs and increasing the yield.

Bridging technology and tradition

Although precision agriculture has many advantages, its success relies upon on how well technology integrates with conventional farming strategies. Understanding the unique requirements of a particular location may be substantially aided via the records and expertise that nearby farmers have amassed over many generations. Precision farming must be considered as an enhancement to conventional methods rather than as a alternative for them.

For example, statistics from soil sensors may be included with conventional information regarding crop rotation and soil fertility to create fertilization plans which are greater a success. In a similar vein, meteorological information and predictive analytics can be used to optimize planting and harvesting times, which might be often decided via regional climatic developments and cultural customs. Farming structures that are extra resilient and sustainable might also end result from this mixing of generation and custom.

In addition, the implementation of precision agriculture needs to be inclusive, guaranteeing that small-scale farmers and those living in growing regions may also gain these equipment. This calls for the creation of available and less expensive instruments in addition to prices in infrastructure, education, and training. We can close the space among contemporary era and conventional knowledge through providing farmers with the records and assets they want to adopt precision agriculture.

Evolution and history of precision agriculture

The fulfillment of precision farming is a fascinating adventure that highlights the convergence of traditional farming practices with contemporary technological advances. These trends mirror mankind's non-stop quest for increased agricultural productivity, sustainable improvement and employment. Understanding the history and evolution of precision agriculture offers treasured insight into wherein agriculture has come and feasible guidelines for its future

Early agricultural practices

Agriculture has been imperative to human civilization for heaps of years. Early farming practices had been in large part based on trial and mistakes, surpassed down from generation to era. Farmers trusted an in-intensity information of neighborhood ecosystems, seasons and topography to supply plants and control livestock. Techniques such as crop rotation, selective breeding and irrigation were developed as a way to maximize yields and ensure meals protection.

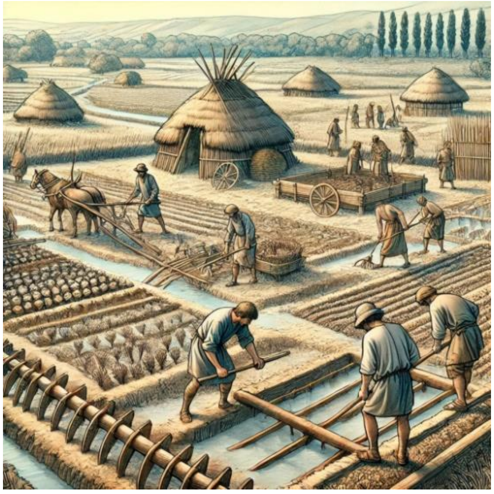

Fig. 1: Illustration of Ancient Farming Techniques

These traditional strategies, even as effective for their time, lacked the precision and efficiency needed to meet the developing needs of more and more massive populations. As societies superior, so did the want for extra cutting-edge agricultural practices.

The agricultural revolution

The first Agricultural Revolution marked a wonderful turning component in farming history. This duration noticed the advent of more advanced equipment and techniques, along with the plow and crop rotation systems, which significantly extended agricultural productiveness. The development of animal-powered machinery allowed farmers to cultivate big areas of land extra effectively.

Fig. 2: 18th Century Plow and Agricultural Tools

The Agricultural Revolution laid the idea for future improvements through the usage of demonstrating the ability of mechanization and superior farming strategies to enhance productivity. However, the reliance on guide exertions and animal strength additionally highlighted the constraints of traditional techniques in scaling up manufacturing.

The industrial revolution and mechanization

The Industrial Revolution in the 18th and 19th centuries introduced approximately profound modifications in agriculture. The introduction of steam-powered gadget, and later inner combustion engines, revolutionized farming operations. Tractors, harvesters, and different mechanized machine changed guide tough paintings, drastically developing the scale and overall performance of agricultural manufacturing.

Mechanization decreased the time and hard paintings required for farming obligations, allowing farmers to manipulate large plots of land and bring greater portions of meals. This duration moreover observed the improved use of chemical fertilizers and insecticides, which similarly boosted crop yields however also delivered new environmental disturbing conditions.

The green revolution

The mid-20th century added the Green Revolution, a length characterised by using the arrival of high-yielding crop kinds, artificial fertilizers, and advanced irrigation strategies. Spearheaded by using agricultural scientists like Norman Borlaug, the Green Revolution aimed to combat global starvation and improve food security, particularly in developing countries.

The Green Revolution achieved exceptional achievement in increasing agricultural output, stopping famines, and helping population boom. However, it additionally caused unintended consequences, which includes soil degradation, water shortage, and a lack of biodiversity because of the huge use of chemical inputs and monoculture practices.

The advent of digital technologies

As the virtual age emerged inside the overdue twentieth and early twenty first centuries, agriculture started out to include records generation and automation. The improvement of Geographic Information Systems (GIS) and Global Positioning Systems (GPS) enabled farmers to map their fields with extraordinary accuracy. These technology laid the inspiration for precision agriculture via bearing in mind more special and data-pushed control of farming operations.

The integration of computer systems and software into agricultural practices made it simpler to gather and analyze greater statistics, ensuing in more knowledgeable selections, farmers can now correctly screen crop fitness, soil situations and climate, make optimizing inputs and improving usual

The rise of precision agriculture

With the developing recognition of the shortcomings of conventional farming methods, a greater sustainable method turned into required. In the latter half of the 20th century, precision agriculture—additionally called smart farming—commenced to take shape. It is characterized by using the software of generation to agricultural fields to monitor and manage crop and soil variability. Optimizing field-degree control about crop farming is the goal.

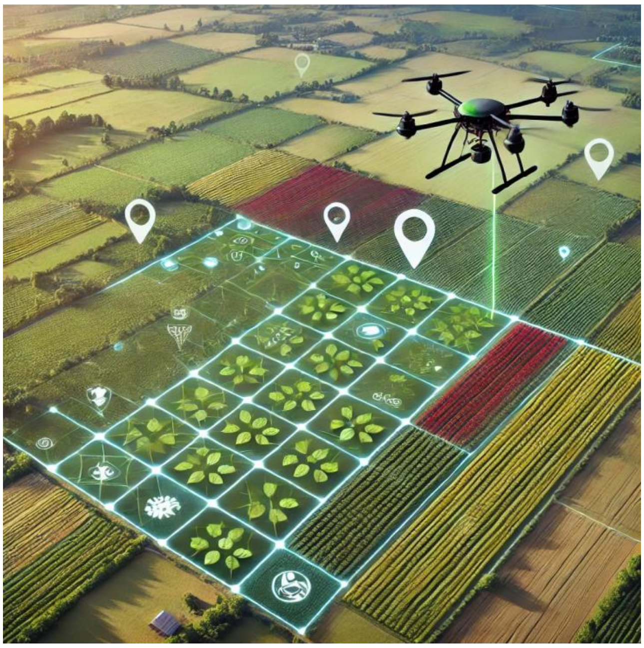

Fig. 3: Advancements in Agriculture

Data, accumulated through a number of techniques inclusive of satellite imaging, GPS, drones, sensors, and Internet of Things devices, is the muse of precision agriculture. In order to limit waste and maximize efficiency, this information is examined to help with planting, fertilization, watering, and harvesting decisions. Precision agriculture gives web site-unique control, which permits specific areas of a subject to be dealt with otherwise depending on their particular characteristics, in evaluation to conventional agriculture's one-length-fits-all approach.

Precision agriculture, additionally called clever farming, emerged as a reaction to the constraints of conventional farming strategies. It represents a shift in the direction of a greater facts-pushed and era-centric approach to farming, aiming to optimize subject-stage management in regards to crop farming.

Precision agriculture leverages a variety of technology, which include GPS, far off sensing, IoT gadgets, and massive statistics analytics, to display and manage agricultural operations with high precision. This technique lets in for web page-precise management, where exceptional regions of an area can be dealt with otherwise primarily based on their precise situations, thereby increasing performance and lowering waste.

Internet of Things (IoT) and Sensor Networks: IoT gadgets along with soil moisture sensors, climate stations, and crop health video display units offer actual-time information on various factors of the farming environment. This facts is crucial for making knowledgeable choices approximately irrigation, fertilization, and pest manipulate.

Fig. 4: Drone Technology

The role of research and development

The key enablers responsible for the increases in precision agriculture have been research and development (R&D). The farmers globally are served by a blend of universities, research institutes and the private sector in the development of new concepts and implementation of technologies that will enhance the farmers' productivity. New technologies in machine learning, artificial intelligence and biotechnology are finding new frontiers in precision agriculture The main concern in innovation is producing a complete precision agriculture solution that is cost effective, simple to implement and highly efficient. For example, improvements in machine learning algorithm are enhancing Crop Yield Predictability whereas Improving in Sensor Technology Experts are helping in improving the efficiency & efficacy in data acquisition at lesser cost.

Precision agriculture: A technology of the twenty-first century

Remarkably, in the 21st century, the association of precision agriculture with sustainability as well as digital transformation in general is not phenomenal. The ideas like smart farming, sustainable intensification, and regenerative agriculture are now merged and layered with precision agriculture technologies.

Precision agriculture is inclined towards current issues like climate change, shrinking resources, and the need for sustainability in agriculture. New inventions that use blockchain for transparency in the supply chain, artificial intelligence for predicting analytics, and robots for autonomous operations are changing the future of farming community.

Impact on farmers and the agricultural industry

It is none a secret that the development of PA has greatly impacted the lives of farmers as well as affected the whole agriculture segment. Farmers who use such strategies in farming get better yields, reduced costs and lesser effects on the environment. Moreover, precision agriculture also introduces the need of an additional use of more of an informative type of approach, where the farmer then has the ability to make the correct decisions of wanting.

On the other hand, the agricultural industry has also benefited from the advanced systems of precision agriculture. This has made the market of precision farming to be innovative due to the development of new products and services by agribusinesses and technology providers. In addition, precision agriculture has contributed to the development of agtech startups leading to increase of innovation and competition in the sector.

Challenges and future directions:

Despite all its advantages, the changes taking place in the area of precision agriculture are not without difficulties. The high initial costs, the need to possess the technical expertise, and data privacy and security concerns can potentially limit the extent of adoption. Besides, there remains a digital gap between large-size and small-size farmers, as well as developed and developing countries.

Future directions for precision agriculture require coping with these issues by the ongoing innovation, increased accessibility, and policy support. There are efforts underway to commercialize affordable technologies, to organize training and education for farmers, and to set up data governance frameworks that safeguard privacy while facilitating the benefits of data-driven farming.

Challenges and opportunities:

Precision farming implementation is not without its difficulties. Some of the obstacles preventing wider adoption are high upfront costs, the requirement for technological know-how, and worries about data security and privacy. Furthermore, farmers run the risk of becoming technologically dependent, depending on intricate systems that could be challenging to maintain or fix on their own without outside help.

Nevertheless, these difficulties are greatly outweighed by the benefits that precision agriculture offers. Precision agriculture can support farming's long-term viability by lowering input costs, raising yields, and limiting environmental effect. Additionally, it creates new avenues for innovation, such as the creation of climate change-resistant crops or the application of blockchain technology to guarantee the transparency and traceability of food.

An important advancement in farming's history is precision agriculture. It provides a comprehensive approach to agriculture that honors the past while welcoming the future by bridging the gap between technology and tradition. A more sustainable, effective, and productive agricultural system that can handle the challenges of the twenty-first century while maintaining the cultural legacy of farming communities is possible if precision agriculture is successfully incorporated into conventional farming operations. It is crucial to keep in mind the value of tradition and the knowledge that accompanies it while we innovate and create new technology. A better future for agriculture can be achieved through the combined use of tradition and technology.

Challenges in espousing precision agriculture

Despite that process, the sacrifice of maintaining perfection is not without its challenges. High cost outsourcing, special moxie requirements, and data storage initiatives are some of the walls growers face when considering equity compliance

Value The primary funding requirements for perfection training technology can be substantial, especially for small manufacturers. Organizations such as GPS systems, drones, and IoT bias can be expensive, and the cost of ongoing maintenance and software updates can be substantial. Financial incentives, subsidies, or cost-sharing arrangements may be needed to spread manufacturers of these technologies.

Specialized Expertise Specific commands require a level of specialized expertise that may not be readily available to all practitioners. Interpreting data from sensors, using drones, or managing automated service delivery can be problematic, especially for the elderly or them located in developing areas. Providing training and support is essential to help growers overcome these walls and fully benefit from uniform training.

Data storage: Storing and processing data with accuracy Companies are increasingly concerned about retrieval and security. Producers are reluctant to capture data on their farms, crops, or practices for fear that this data could be misused. What is surprising is that there is a need to trust that data is safely stored and used responsibly and to encourage the abandonment of perfectionist technologies. infrastructure Many ranches lack the infrastructure needed to support equal parenting. For example, reliable Internet connectivity is essential for transmitting data from IoT bias or pall- grounded analytics platforms. Ensuring that all producers can benefit from equity farming requires investment in livestock management.

The future of precision agriculture

The future of Siddhipal depends on its ability to adapt and evolve with the changing needs of global agricultural land. As technology advances, equity preservation is likely to become indeed comprehensive, and new tools and methods will arise to meet the challenges of 21st century agriculture.

One area of clear growth is the use of blockchain technology in equity storage. Blockchain can provide a secure and transparent way to track the entire lifecycle of a crop, from planting to harvest to request. This can help improve traceability, improve food safety and consumer confidence in the food energy chain.

Another promising development is the integration of equal parenting into restorative parenting practices. Regenerative stewardship focuses on restoring and improving soil and ecosystem health, usually through practices such as cover crops, fallow, and agroforestry Precision stewardship can take these actions round to provide the data and tools required to manage it effectively, icing farms to make it productive and sustainable.

Artificial intelligence and machine technology will continue to play an important role in preserving equality in the future. As this technology becomes more advanced, it will enable truly accurate forecasts and recommendations, helping manufacturers optimize every aspect of their operations.

Precision husbandry represents a brand new frontier in husbandry, supplying the eventuality to increase productiveness, lessen environmental effect, and ameliorate the sustainability of agrarian practices. By integrating advanced technology with traditional husbandry understanding, perfection husbandry islands the distance among the history and the future, developing a greater flexible and powerful agrarian device.

Nevertheless, the success perpetration of perfection husbandry requires addressing several demanding situations, which includes price, specialized moxie, facts sequestration, and shape. By prostrating these partitions and icing that perfection husbandry is offered to all growers, we can unleash its complete eventuality and pave the way for a brighter destiny in husbandry.

This chapter highlights the importance of embracing each era and subculture in the pursuit of sustainable husbandry. By doing so, we are able to produce a husbandry gadget that now not handiest meets the necessities of second but additionally preserves the coffers and understanding demanded for unborn generations.

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PRECISION AGRICULTURE: BRIDGING TECHNOLOGY AND TRADITION VOLUME II

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