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RESEARCH AND REVIEWS IN AGRICULTURE SCIENCE VOLUME I

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PREFACE

Agriculture is the cornerstone of human civilization, providing sustenance, raw materials, and economic stability for societies around the world. As our global population continues to grow and environmental challenges become increasingly complex, the importance of agriculture in ensuring food security, environmental sustainability, and economic prosperity cannot be overstated. To meet these challenges, agricultural science has evolved rapidly, embracing interdisciplinary approaches, technology-driven solutions, and sustainable practices.

In this book, we have gathered a selection of research papers and reviews that delve into various facets of agriculture, from crop science and livestock management to soil health, agribusiness, and the integration of cutting-edge technologies. Each chapter represents a unique contribution to the ongoing dialogue in agricultural science, shedding light on emerging trends, innovative methodologies, and critical insights that have the potential to shape the future of agriculture.

The content within these pages spans a wide spectrum of topics, providing a holistic view of the challenges and opportunities that lie ahead in agriculture. Whether you are a seasoned researcher, a student embarking on a journey in agricultural science, or a stakeholder in the agriculture industry, we believe that this book will offer valuable perspectives and inspire further inquiry into the fascinating and ever-evolving field of agriculture.

We extend our gratitude to the authors who have generously shared their expertise and findings, as well as the reviewers who have dedicated their time and expertise to ensure the quality and rigor of the content presented here. This collaborative effort is a testament to the spirit of inquiry and the shared commitment to advancing agricultural knowledge.

As we navigate the complexities of feeding a growing global population, protecting our natural resources, and fostering sustainable agricultural practices, it is our hope that "Research and Reviews in Agriculture Science" will serve as a valuable resource and source of inspiration for all those engaged in the pursuit of a more resilient and sustainable future for agriculture.

Editors

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FOSTERING SUSTAINABLE AGRICULTURE THROUGH INTEGRATED AGRICULTURAL SCIENCE EDUCATION: GENERAL OVERVIEW AND LESSONS FROM STUDIES

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Abstract:

The growing challenges of global food security and environmental degradation call for innovative solutions that prioritize sustainability in agriculture. This comprehensive study explores the pivotal role of agricultural science education in promoting sustainable farming practices. As the global population surges towards 9.7 billion by 2050, ensuring a consistent and nutritious food supply becomes imperative. However, escalating environmental issues, including soil degradation, water scarcity, and climate change, pose threats to agricultural productivity and ecological balance. Sustainable farming practices offer a holistic approach that not only enhances agricultural output but also safeguards the environment for future generations. This study delves into the current landscape of agricultural education programs, curricula, and teaching methodologies across various educational levels. It highlights the importance of integrating sustainable farming concepts, including soil health, biodiversity, water conservation, and integrated pest management. Real-world examples of successful sustainable farming models from around the world showcase the potential impact of effective education on improved farm productivity, environmental conservation, and economic resilience. To facilitate the integration of sustainable farming topics into curricula, strategies are presented, encompassing multidisciplinary approaches, case studies, and participatory learning. Moreover, the review underscores the role of technology, online resources, and practical training in enhancing educational effectiveness. Considering the challenges ahead, the study emphasizes the need for comprehensive assessment methods to evaluate the impact of agricultural education on promoting sustainable practices. Policymakers are urged to prioritize funding, advocate for curriculum integration, and create an enabling environment that supports the integration of sustainable farming education. The review concludes with a compelling call to action for educators, researchers, policymakers, and stakeholders to collaborate in advancing sustainable agriculture through education.

Keywords: sustainable agriculture, agricultural science education, curriculum integration, environmental conservation, food security, educational outreach, policy implications.

Introduction:

Sustainable farming practices play a pivotal role in addressing the interconnected challenges of global food security and environmental preservation. As the global population continues to expand, projected to reach 9.7 billion by 2050, ensuring a consistent and nutritious food supply becomes increasingly crucial. At the same time, escalating environmental issues, such as soil degradation, water scarcity, and climate change, pose threats to agricultural productivity and the overall ecosystem. In this context, sustainable farming practices offer a holistic approach that not only enhances agricultural output but also safeguards the environment for future generations (UN, 2019).

At the heart of sustainable farming lies agroecology, an evidence-based approach that emphasizes the harmonious alignment of agricultural systems with local ecosystems. Anchored in practices such as crop rotation, intercropping, and agroforestry, agroecology not only optimizes land utilization but also fosters biodiversity and soil health (IPES-Food, 2016). For instance, the implementation of intercropping, involving the simultaneous cultivation of diverse crops in close proximity, results in resource optimization, pest control, and soil enrichment (Altieri, 2018). Research underscores the potential of such practices to yield increased crop productivity and heightened food security (Bommarco *et al.,* 2013). Furthermore, embracing sustainable farming practices manifests as a potent tool for curbing greenhouse gas emissions and ameliorating climate change ramifications. Conventional agricultural practices, characterized by excessive fertilizer application and land transformations, significantly contribute to greenhouse gas emissions. Conversely, sustainable techniques such as conservation tillage and cover cropping bolster carbon sequestration and soil organic matter, thus reinforcing climate resilience (Smith *et al.*, 2008). The Food and Agriculture Organization (FAO) underscores the role of these practices in curtailing emissions per unit of yield, thereby ushering in a more sustainable food production system (FAO, 2017).

A pivotal facet of sustainable agriculture is the judicious preservation of water resources, especially within the context of burgeoning water scarcity concerns. Precision irrigation techniques, including drip and micro-sprinkler systems, precisely target water supply to plant roots, curbing wastage and elevating water utilization efficiency (Keller & Bliesner, 1990). This assumes paramount significance as agriculture accounts for nearly 70% of global freshwater withdrawals (UN Water, 2021). The adoption of such water-efficient technologies enables farmers to sustain crop productivity while alleviating stress on water reservoirs. The nexus between agricultural science education and the empowerment of farmers with the requisite knowledge and skills for sustainable practices comes into focus.

In essence, this chapter centers on the convergence of agricultural science education and its cascading impact. As the agricultural landscape navigates escalating challenges, the call for a comprehensive educational approach resonates strongly. This chapter traverses the pivotal role that agricultural science education plays in endowing individuals with the acumen to navigate the multifaceted and interlinked challenges encountered by the agricultural sector. By delving into the symbiotic relationship between education and agriculture, it underscores how a holistic education empowers stakeholders to grapple with an intricate web of challenges, from food security to sustainability. Moreover, it emphasizes the transformative potential of integrating agricultural science education across diverse educational tiers. By elucidating the repercussions of such integration on individuals, communities, and the broader society, the chapter elucidates how well-informed and educated agricultural practitioners can foster innovation, resilience, and the sustainable development of the sector. Fueled by empirical evidence, real-world cases, and expert insights, the chapter articulates the manifold dividends of agricultural science education—ranging from elevated farming practices and resource management to refined policy formulation and technology assimilation.

Agricultural science education: Current landscape

1. Overview of agricultural education programs: The landscape of agricultural education programs spans across multiple educational levels, from primary to higher education. At the primary level, agricultural concepts are often introduced through interdisciplinary approaches, emphasizing the interconnectedness of food production, environment, and society. In secondary education, more specialized agricultural science courses provide students with a deeper understanding of topics such as crop cultivation, animal husbandry, and agribusiness management (Girard & Mougeot, 2019). Additionally, vocational institutions offer hands-on training, equipping learners with practical skills relevant to farming and related industries. At the higher education level, universities offer comprehensive agricultural science programs that encompass areas like agronomy, horticulture, agricultural engineering, and sustainable resource management.

2. Curricula and teaching methodologies in agricultural science: The curricula and teaching methodologies in agricultural science education have evolved to address contemporary challenges and technological advancements. Curricula often blend theoretical knowledge with practical experiences to foster a well-rounded understanding of the field (Lindner *et al.*, 2017). Emphasis is placed on equipping students with skills related to precision agriculture, biotechnology, and sustainable practices. Innovative teaching approaches include experiential learning, case studies, and field trips, allowing students to engage directly with real-world agricultural scenarios (Abdullah *et al.,* 2020). Moreover, technology integration, such as using agricultural simulation software or remote sensing tools, enhances students' ability to analyze complex agricultural systems.

3. Challenges and opportunities: While agricultural science education has made substantial progress, challenges remain. Outdated curricula can hinder students' preparedness for modern agricultural practices, which increasingly demand a blend of traditional wisdom and contemporary techniques (Taylor *et al.,* 2016). Additionally, the perception of agriculture as a less attractive career path poses recruitment challenges. However, these challenges present opportunities for curriculum innovation. By incorporating interdisciplinary approaches, addressing emerging global issues like climate change adaptation, and promoting agri-entrepreneurship, agricultural education can attract a diverse range of students and foster innovation in the field (Gebremedhin & van der Werf, 2017).

4. Empowering sustainable agriculture: Agricultural science education plays a pivotal role in advancing sustainable agriculture. By integrating principles of agroecology and environmental stewardship into curricula, educational institutions can instill in students a deep understanding of the importance of biodiversity, soil health, and resource efficiency (Hart *et al.,* 2017). Graduates equipped with such knowledge are better positioned to implement regenerative practices that enhance ecosystem resilience and mitigate the negative impacts of conventional farming methods. Moreover, agricultural education fosters a culture of continuous learning, encouraging professionals in the field to stay updated with the latest scientific advancements and best practices. The current landscape of agricultural science education encompasses diverse educational levels and incorporates evolving curricula and teaching methodologies. By addressing challenges, embracing technological advancements, and emphasizing sustainability, agricultural education not only equips individuals with the skills they need to succeed in the sector but also contributes to the broader goal of fostering resilient and sustainable agricultural systems.

Examination of curricula and teaching methodologies in agricultural science

The curricula and teaching methodologies employed in agricultural science education have undergone significant transformations in response to changing agricultural landscapes and educational paradigms. These changes reflect a broader recognition of the need to equip students with not only foundational knowledge but also practical skills that align with modern agricultural practices and sustainability principles.

1. Innovative curricula integration: Contemporary curricula in agricultural science have shifted from being solely production-focused to embracing a more holistic and interdisciplinary approach. They emphasize the integration of subjects like biology, ecology, economics, and technology, acknowledging the complex nature of modern agriculture (Escobar & Francis, 2019). This integration enables students to comprehend the multifaceted challenges faced by the agricultural sector, from addressing food security to mitigating environmental impacts. Curricula often incorporate case studies, real-world projects, and experiential learning opportunities to provide students with tangible connections between theoretical concepts and practical applications (Mamo *et al.,* 2017).

2. Hands-on and experiential learning: Teaching methodologies in agricultural science have evolved to prioritize hands-on and experiential learning. Farm visits, fieldwork, and internships offer students direct exposure to agricultural practices, allowing them to apply theoretical knowledge in real-world contexts. These experiences cultivate critical thinking, problem-solving skills, and a deep understanding of the challenges and intricacies of agriculture (Lamm *et al.*, 2020). Furthermore, simulation tools and agricultural technology platforms enable students to explore scenarios and make informed decisions virtually, enhancing their decision-making skills (Abdullah *et al.*, 2020).

3. Sustainability and systems thinking: Modern agricultural science curricula increasingly emphasize sustainability and systems thinking. Students are introduced to concepts like agroecology, soil health, integrated pest management, and resource-efficient practices. These elements encourage learners to perceive agriculture as part of broader ecosystems and to consider the long-term consequences of their actions (Hart *et al.*, 2017). This shift in focus helps foster environmentally responsible practices and equips students to address challenges like climate change adaptation and resource scarcity.

4. Incorporating technology and digital learning: The integration of technology and digital learning tools has revolutionized agricultural education. Online platforms, virtual laboratories, and remote sensing technologies enable students to engage with agricultural concepts beyond the classroom (Gottlieb *et al.*, 2020). Moreover, digital resources facilitate access to current research, data, and information, empowering students to stay updated with the latest trends and advancements in the field.

The examination of curricula and teaching methodologies in agricultural science reveals a dynamic shift towards interdisciplinary, experiential, and sustainability-focused education. By blending theory with practical application, these approaches better prepare students for the challenges and opportunities inherent in modern agriculture. As agriculture continues to evolve, so too does the education that underpins its progress, ensuring that future agricultural professionals are well-equipped to navigate the complexities of a changing world.

Key principles of sustainable agriculture

Sustainable agriculture is guided by a set of principles that prioritize environmental stewardship, social equity, and economic viability. These principles revolve around holistic approaches that aim to maintain the long-term health of both ecosystems and agricultural systems. The core tenets of sustainable farming encompass soil health, biodiversity, water conservation, and integrated pest management, working together to create resilient and regenerative agricultural practices.

1. Soil health: Central to sustainable farming is the principle of soil health. Healthy soils are a foundation for productive agriculture, as they support nutrient cycling, water retention, and plant growth. Sustainable farming practices prioritize soil conservation, reducing erosion through techniques like cover cropping and reduced tillage (Lal, 2015). Additionally, the application of organic matter, such as compost and cover crop residues, enhances soil structure, nutrient availability, and microbial diversity, fostering a fertile and resilient soil ecosystem.

2. Biodiversity: Biodiversity is a key principle that emphasizes the importance of a diverse range of plant and animal species within agricultural systems. In sustainable farming, biodiversity contributes to ecosystem resilience, as varied species help control pests, promote pollination, and maintain nutrient cycles (Bommarco *et al.,* 2013). Agroforestry, intercropping, and crop rotation are examples of practices that enhance biodiversity by mimicking natural ecosystems and reducing the reliance on monoculture, which can lead to increased vulnerability to diseases and pests.

3. Water conservation: Sustainable farming practices prioritize efficient water management to address the growing challenge of water scarcity. Techniques such as drip irrigation, rainwater harvesting, and precision watering systems minimize water wastage and optimize water delivery to crops (FAO, 2012). Additionally, water-efficient crop selection and soil moisture monitoring enable farmers to make informed decisions regarding irrigation, ensuring that water resources are used wisely and sustainably.

4. Integrated Pest Management (IPM): Integrated Pest Management is a holistic approach to pest control that minimizes the use of synthetic chemicals and focuses on natural ecological processes. IPM involves the integration of various strategies, including biological control, crop rotation, and the use of resistant crop varieties, to prevent pest outbreaks (Van Lenteren, 2012). By emphasizing the preservation of beneficial insects and ecological balance, IPM reduces the negative impacts of pesticide use on both human health and the environment.

The key principles of sustainable farming, including soil health, biodiversity, water conservation, and integrated pest management, embody a comprehensive framework for nurturing resilient and regenerative agricultural systems. By embracing these principles, farmers contribute not only to the health and vitality of their own lands but also to the preservation of global ecosystems and the well-being of future generations.

Showcase of successful sustainable farming models from around the world

Across the globe, innovative farmers have embraced sustainable farming models that demonstrate the viability of ecologically sound and economically viable agricultural practices. These successful models showcase the transformative potential of sustainable approaches in addressing pressing challenges while promoting environmental health and food security.

1. Agroforestry in Costa Rica: In Costa Rica, agroforestry systems have gained prominence for their ability to restore degraded land, enhance biodiversity, and provide multiple income streams. The Finca Luna Nueva Lodge is a notable example. They practice agroforestry by integrating fruit trees, medicinal plants, and spices with traditional crops like coffee and cacao. This approach fosters ecological balance, prevents soil erosion, and contributes to carbon sequestration while generating revenue from diverse agricultural products (Montagnini, 2006).

2. SRI rice cultivation in India: The System of Rice Intensification (SRI) is an innovative method that has transformed rice cultivation in India. SRI focuses on improving root growth, managing water efficiently, and using organic matter to enhance soil health. Farmers in states like Tamil Nadu and Bihar have reported significant increases in yields and reductions in water usage through SRI practices (Uphoff, 2015).

3. Organic farming in Denmark: Denmark has embraced organic farming with remarkable success. The country's "Organic Action Plan" has incentivized farmers to transition to organic practices by offering financial support and technical assistance. This approach has not only boosted organic food production but also reduced the environmental impact of conventional farming practices, including pesticide and fertilizer use (Kledal *et al.,* 2018).

4. Terraced farming in Peru: In the highlands of Peru, indigenous communities have practiced terraced farming for centuries. These intricate systems of terraces, known as "andenes," enable agriculture on steep slopes while preventing soil erosion. By preserving traditional knowledge and maintaining these terraced landscapes, farmers continue to produce crops such as potatoes and quinoa while safeguarding their cultural heritage and promoting sustainable land use (Bury *et al.,* 2013).

5. Community- supported agriculture in the USA: Community-supported agriculture (CSA) models have flourished in the United States. Farms like The Land Connection in Illinois involve local communities in the agricultural process by providing shares of produce to members. This not only ensures a direct connection between consumers and producers but also supports small-scale, sustainable farming practices by providing a stable market for farmers (Allen, 2003).

These successful sustainable farming models from different corners of the world underscore the adaptability and effectiveness of innovative approaches in addressing agricultural and environmental challenges. By prioritizing principles such as agroforestry, organic farming, and water-efficient cultivation, these models exemplify how sustainable agriculture can enhance productivity, preserve ecosystems, and contribute to the well-being of both rural communities and the planet.

Integrating sustainable farming concepts into curricula: Strategies for embedding sustainable farming topics into agricultural science courses

Integrating sustainable agriculture concepts into agricultural science curricula is a critical endeavor in equipping future agricultural professionals with the knowledge and skills to address the challenges of a changing world. To effectively embed sustainable farming topics into courses, educators can utilize various strategies that promote a holistic understanding of agricultural practices, environmental stewardship, and economic viability.

1. Cross-disciplinary approaches: One effective strategy for integrating sustainable farming concepts is through cross-disciplinary approaches that span different areas of agricultural science. Courses can be designed to explore the interplay between agronomy, ecology, economics, and sociology. For instance, a course on sustainable agriculture might investigate the ecological benefits of crop rotations, while also analyzing the economic implications for farmers (Gliessman, 2018). This approach provides students with a comprehensive understanding of how various disciplines converge within the realm of sustainable farming.

2. Experiential learning: Experiential learning plays a pivotal role in embedding sustainable farming concepts into curricula. Institutions can establish demonstration farms or partner with local sustainable farms to offer students hands-on experiences. These experiences might include soil testing, composting, and integrated pest management workshops. Such activities enable students to directly engage with sustainable practices, fostering a deeper connection between theory and real-world application (Allen, 2004).

3. Case studies and problem-based learning: Case studies can effectively illustrate successful sustainable farming models and the challenges they address. By incorporating case studies from diverse geographic regions, educators can encourage students to analyze the applicability of these models within different contexts (Hart *et al.*, 2017). Problem-based learning scenarios can task students with devising solutions to specific sustainability challenges, enhancing critical thinking and problem-solving skills.

4. Technology integration: The integration of technology can enhance students' engagement with sustainable farming concepts. Virtual farm simulations, online tools for crop planning, and precision agriculture software offer students a platform to explore sustainable practices in a digital environment (Gottlieb *et al.*, 2020). This approach bridges the gap between theoretical learning and practical implementation.

5. Research and projects: Integrating sustainability-focused research projects into the curriculum empowers students to apply their knowledge to real-world issues. Assigning projects that involve designing and executing sustainable farming experiments allows students to gain practical experience while contributing to the advancement of sustainable agricultural practices (Beecher *et al.*, 2007).

6. Guest speakers and industry collaboration: Guest speakers, including farmers, agricultural experts, and sustainability advocates, can provide valuable insights from their experiences in the field. Collaborating with industry partners for internships or cooperative education programs offers students the opportunity to work on farms practicing sustainable methods, thereby facilitating the practical application of their classroom learning (Campbell *et al.,* 2016).

7. Longitudinal learning: To ensure a comprehensive understanding of sustainable farming, educators can adopt a longitudinal approach that progressively builds upon foundational knowledge. Introducing sustainable concepts at various levels of study allows students to grasp the interconnected nature of agricultural systems over time (Ponder *et al.,* 2009).

8. Assessments and reflections: Including assessments that evaluate students' comprehension of sustainable farming concepts encourages active learning. Additionally, incorporating reflective assignments prompts students to analyze the ethical, social, and environmental implications of different agricultural practices, fostering a deeper understanding of sustainability issues (Lindemann-Matthies *et al.,* 2015). By employing these strategies, educational institutions can effectively integrate sustainable farming concepts into agricultural science curricula. This holistic approach equips students with the multifaceted knowledge and practical skills needed to navigate the complexities of modern agriculture while promoting environmental stewardship and sustainability.

Case studies of educational institutions implementing innovative teaching approaches

In the realm of agricultural education, several educational institutions have embraced innovative teaching approaches to equip students with the knowledge and skills necessary for sustainable farming practices. These case studies showcase how institutions are redefining traditional teaching methods to foster a deeper understanding of agricultural concepts and promote active engagement in the field.

1. The Land Institute, USA: The Land Institute, based in Kansas, USA, is renowned for its commitment to developing perennial crops and sustainable agriculture. Their educational initiatives incorporate innovative teaching methods that bridge theory and practice. The "Kernza Classroom" program engages students in learning about perennial grain development through hands-on experiences in the fields. This model integrates research, experiential learning, and community engagement, allowing students to actively participate in the development of sustainable agriculture (The Land Institute, n.d.).

2. Wageningen University, Netherlands: Wageningen University in the Netherlands is a global leader in agricultural research and education. The university's "Farm Experience" course stands out as an example of immersive learning. This course takes students out of the traditional classroom setting and places them on working farms. Students engage in various tasks, from planting to harvest, while also learning about the socio-economic aspects of farming. This approach provides students with direct exposure to the realities of farming, fostering a deeper understanding of the challenges and opportunities faced by farmers (Wageningen University, n.d.).

3. University of California, Davis, USA: The University of California, Davis, has integrated technology into its agricultural education programs to enhance student learning. The "Smart Farm" project at UC Davis incorporates sensor technology, data analysis, and precision agriculture principles. Students use real-time data to make informed decisions about crop management, irrigation, and pest control. This hands-on experience with cutting-edge technology not only enhances students' technical skills but also prepares them to embrace the evolving landscape of modern agriculture (UC Davis, n.d.).

4. University of Queensland, Australia: The University of Queensland's Gatton Campus offers an innovative "Paddock to Plate" course. This interdisciplinary course takes students through the entire food production process, from planting seeds to preparing meals. Students learn about sustainable farming practices, food processing, and culinary skills. By connecting theory with practical experiences, the course encourages students to critically evaluate the food system and its environmental impacts while fostering a holistic understanding of agriculture (University of Queensland, n.d.).

5. Egerton University, Kenya: Egerton University in Kenya has embraced experiential learning through its "Community Based Education and Service" (COBES) program. COBES involves students working with local communities to address agricultural and environmental challenges. This program not only enriches students' understanding of sustainable farming practices but also empowers them to contribute positively to rural development. Students collaborate with farmers to implement practical solutions, ensuring that classroom knowledge is translated into meaningful impact (Egerton University, n.d.).

These case studies illustrate how educational institutions worldwide are breaking away from traditional teaching approaches and embracing innovative methods to educate future agricultural leaders. By integrating experiential learning, technology, interdisciplinary approaches, and community engagement, these institutions are equipping students with the practical skills and knowledge needed to address the complexities of modern agriculture and promote sustainable farming practices.

Experiential learning and practical training: Enriching understanding of sustainable agriculture techniques

Experiential learning and practical training are integral components of agricultural education that play a pivotal role in enhancing students' understanding of sustainable farming techniques. These hands-on experiences provide a bridge between theoretical knowledge and real-world application, fostering a deeper appreciation for the complexities of agricultural systems while promoting active engagement and critical thinking. Community gardens, farm visits, and on-field workshops serve as effective educational tools that empower students with practical skills, ecological awareness, and a profound connection to the agricultural landscape.

1. Bridging theory and practice: Experiential learning allows students to move beyond textbooks and engage directly with the principles they study. When learning about sustainable farming techniques such as crop rotation, organic pest management, and soil conservation, students gain a firsthand understanding of the challenges and benefits associated with these practices. This practical engagement fosters a deeper comprehension of how theories are translated into action within real-world agricultural settings (Hart *et al.,* 2017).

2. Community gardens as living laboratories: Community gardens serve as living laboratories where students can experiment with sustainable farming methods in a controlled yet authentic environment. These spaces encourage collaboration and knowledge sharing among students, educators, and community members. Students gain practical experience in planting, cultivating, and maintaining crops while also observing the impacts of different approaches on soil health, biodiversity, and local ecosystems (Bryant & Jones, 2012).

3. Farm visits: Learning from the source: Farm visits provide students with direct exposure to the day-to-day operations of working farms. By observing sustainable practices in action, students witness the application of techniques they've learned in class. Conversations with farmers offer insights into the decision-making process behind sustainable choices and the challenges faced in implementing these practices. This firsthand experience helps students develop a comprehensive understanding of the nuances and intricacies of sustainable farming (Bloom *et al.,* 2005).

4. On-field workshops: Hands-on learning: On-field workshops are dynamic settings for interactive learning. Workshops led by experienced farmers, researchers, and agricultural experts provide students with the opportunity to participate in activities like soil testing, composting, and integrated pest management. Through direct engagement, students grasp the practical skills required to implement sustainable techniques effectively (Abdullah *et al.,* 2020).

5. Cultivating environmental stewardship: Experiential learning instills a sense of environmental stewardship in students. As they witness the interconnectedness of ecosystems, the importance of soil health, and the role of biodiversity in sustainable farming, students develop a heightened appreciation for the delicate balance between human activity and nature. This awareness encourages responsible decision-making and a commitment to preserving the environment for future generations (Lamm *et al.,* 2020).

Experiential learning and practical training offer a transformative educational experience that extends beyond the classroom. Community gardens, farm visits, and on-field workshops provide students with a tangible connection to sustainable farming techniques. By immersing students in real-world agricultural contexts, these approaches foster critical thinking, promote ecological understanding, and equip the next generation of agricultural professionals with the skills needed to navigate the complexities of sustainable farming.

Technology in agricultural education

Utilization of digital tools, simulations, and virtual reality for teaching sustainable farming concepts. The integration of technology into agricultural education has revolutionized the way sustainable farming concepts are taught and understood. Digital tools, simulations, and virtual reality have opened new avenues for experiential learning, while online resources and platforms provide access to up-to-date information on sustainable practices. These technological advancements enhance students' engagement, offer immersive experiences, and ensure they are well-equipped to navigate the complexities of sustainable agriculture.

1. Digital tools and simulations: Enhancing understanding: Digital tools and simulations allow students to interact with complex agricultural systems and experiment with various scenarios. Simulation software can model crop growth, weather patterns, and pest dynamics, enabling students to observe the outcomes of different sustainable farming strategies (Gottlieb *et al.*, 2020). These tools offer a risk-free environment for testing hypotheses, making decisions, and analyzing the consequences of different choices.

2. Virtual Reality (VR) and Augmented Reality (AR): Immersive Learning: Virtual reality and augmented reality technologies provide immersive learning experiences by transporting students to virtual agricultural landscapes. Students can explore farms, witness sustainable practices, and even interact with virtual elements (Kaufmann & Schmalstieg, 2003). VR and AR enhance engagement by making abstract concepts tangible and creating memorable experiences that resonate with students long after the learning session.

3. Online resources and platforms: Access to information: The digital era has brought forth an abundance of online resources and platforms that offer access to up-to-date information on sustainable farming practices. Websites, blogs, webinars, and e-learning platforms provide students with a wealth of knowledge from experts around the world. For instance, resources like the Food and Agriculture Organization's (FAO) online learning modules on sustainable agriculture empower students to learn at their own pace while staying informed about the latest trends (FAO, n.d.).

4. Data analytics and precision agriculture: Real-time insights: Technology-driven data analytics enable students to analyze real-time data collected from farms. This data can be used to assess crop health, soil moisture levels, and pest occurrences. Precision agriculture tools allow students to make informed decisions about resource allocation and the application of inputs, promoting efficient and targeted practices (Scharf *et al.*, 2005).

5. Interactive workshops and webinars: Global learning: Technology facilitates interactive workshops and webinars that connect students with experts, practitioners, and researchers from different parts of the world. These sessions provide students with diverse perspectives on sustainable farming, enabling them to understand how sustainable practices vary based on geographic and climatic conditions (Campbell *et al.*, 2016). The integration of technology into agricultural education has transformed the teaching and learning of sustainable farming concepts. Digital tools, simulations, virtual reality, online resources, and interactive platforms offer dynamic and engaging methods for students to explore, learn, and apply principles of sustainable agriculture. By embracing technology, educational institutions empower students to become proficient in utilizing digital tools while equipping them with the knowledge and skills needed to navigate the ever-evolving landscape of sustainable farming.

Online resources and platforms for accessing up-to-date information on sustainable agricultural practices

In the digital age, a plethora of online resources and platforms provide easy access to the latest information on sustainable farming practices. These resources empower students, farmers, researchers, and enthusiasts to stay informed about advancements in sustainable agriculture, enabling them to make informed decisions and contribute to a more resilient and environmentally conscious food system.

1. Food and Agriculture Organization (FAO) e-learning modules: The FAO offers a range of e-learning modules on sustainable agriculture topics. These modules cover various aspects of sustainable farming, such as soil management, water conservation, agroforestry, and organic farming. They provide in-depth insights into best practices and their implementation, making them valuable resources for learners worldwide (FAO, n.d.).

2. Sustainable Agriculture Research & Education (SARE): SARE provides an extensive collection of online resources, including guides, case studies, videos, and publications. These resources cover a wide spectrum of sustainable agriculture topics, from crop rotation and integrated pest management to livestock management and agroecology. SARE's resources are tailored to various audience groups, from farmers and educators to researchers and policymakers (SARE, n.d.).

3. AgriTech Tomorrow: AgriTech Tomorrow is a platform that focuses on the intersection of agriculture and technology. It provides insights into innovative technologies and practices that contribute to sustainable farming. The platform covers areas like precision agriculture, smart irrigation, and data-driven decision-making, offering a glimpse into the future of sustainable agriculture (AgriTech Tomorrow, n.d.).

4. Organic Farming Research Foundation (OFRF): OFRF is a valuable resource for those interested in organic farming and agroecology. Their online resources include research reports, fact sheets, and articles that cover a wide range of organic farming practices, from soil health and cover cropping to pest management and crop diversity (OFRF, n.d.).

5. Sustainable Agriculture Education Association (SAEA): SAEA offers resources specifically tailored to educators and students in the field of sustainable agriculture. Their collection includes teaching materials, syllabi, and educational resources that can be integrated into academic curricula. These resources help educators incorporate sustainable farming concepts into their courses (SAEA, n.d.).

6. United Nations Development Programme (UNDP) - Equator Initiative: The UNDP's Equator Initiative showcases community-based solutions for sustainable development. Their platform features stories and case studies from around the world that highlight successful sustainable farming practices implemented by local communities. These stories offer inspiration and practical insights for anyone interested in sustainable agriculture (UNDP, n.d.). These online resources and platforms serve as valuable tools for anyone seeking up-to-date information on sustainable farming practices. Whether you're a student, farmer, researcher, or enthusiast, these resources offer a wealth of knowledge, insights, and practical guidance to foster sustainable agricultural practices and contribute to a more environmentally conscious and resilient food system.

Teacher training and capacity building: Empowering agricultural educators for effective sustainable farming education

Teacher training and capacity building are pivotal components in ensuring that agricultural educators are equipped with the knowledge, skills, and resources needed to effectively teach sustainable farming concepts. These initiatives play a crucial role in preparing educators to inspire and guide students towards a comprehensive understanding of sustainable agricultural practices, thus fostering a new generation of environmentally conscious and skilled agricultural professionals.

1. Comprehensive curriculum development: Teacher training programs should focus on developing comprehensive and up-to-date curricula that encompass a wide range of sustainable farming techniques. Educators should be equipped with the knowledge to integrate interdisciplinary approaches, cutting-edge research, and practical experiences into their teaching methods (Lynch *et al.*, 2019).

2. Experiential learning strategies: Capacity building efforts should emphasize experiential learning strategies that enable educators to incorporate hands-on experiences into their teaching. Workshops and training sessions can provide educators with the skills to design and implement practical activities like field trips, demonstrations, and community engagement projects, enhancing students' practical understanding of sustainable practices (Martinez & Gupta, 2019).

3. Technology integration training: Educators need training in effectively integrating technology and digital tools into their teaching methods. This includes using simulations, online resources, and virtual reality platforms to enhance students' engagement and understanding of sustainable farming concepts (Kumar *et al.*, 2021).

4. Continuous professional development: Capacity building is an ongoing process that should extend beyond initial training. Providing opportunities for continuous professional development through workshops, conferences, and online courses ensures that educators stay updated with the latest advancements in sustainable farming practices and teaching methodologies (Lee *et al.*, 2020).

5. Partnership and collaboration: Collaboration with agricultural experts, practitioners, and industry professionals can provide educators with valuable insights and practical knowledge. Partnerships with local farms, research institutions, and agribusinesses can offer educators real-world exposure to sustainable practices, enriching their teaching with practical examples (Ponder *et al.*, 2009).

6. Pedagogical techniques: Educators should receive training in pedagogical techniques that foster active learning, critical thinking, and problem-solving skills among students. Training programs can explore innovative teaching methods such as case-based learning, flipped classrooms, and project-based assessments to make sustainable farming education engaging and effective (Cubero & Sanchez, 2020).

7. Curriculum adaptation and localization: Teacher training should address the importance of adapting curricula to local contexts and needs. Educators should learn to consider the socio-economic, cultural, and environmental factors of their region when teaching sustainable farming practices, ensuring that students are equipped to address specific challenges (Pitre *et al.*, 2018).

Teacher training and capacity building are essential investments in the future of sustainable farming education. By equipping agricultural educators with the skills to effectively teach sustainable practices, institutions contribute to the development of a knowledgeable and skilled workforce capable of addressing the challenges of modern agriculture while fostering a sustainable and resilient food system.

Educational outreach to farming communities

Educational outreach to farming communities is a vital component of promoting sustainable farming practices. Engaging farmers, local communities, and extension services in educational initiatives facilitates the dissemination of scientific knowledge and practical applications. By tailoring communication strategies, educators can bridge the gap between theoretical concepts and their real-world implementation, fostering a culture of sustainable agriculture and empowering stakeholders to make informed decisions.

1. Farmer-centric workshops and field days: Organizing farmer-centric workshops and field days provides a platform for educators and experts to interact directly with farmers. These events focus on practical skills, demonstrations, and discussions that address farmers' immediate challenges. Sharing successful case studies and showcasing sustainable farming techniques in action builds trust and credibility, encouraging farmers to adopt innovative practices (Llewellyn *et al.,* 2019).

2. Local language and contextualized content: Tailoring educational materials and communication strategies to the local language and context is essential for effective outreach. Using familiar terminology and relatable examples makes complex concepts more accessible and relevant to farmers. This approach enhances understanding and encourages farmers to apply sustainable practices in their own fields (Garforth *et al.,* 2019).

3. Participatory learning approaches: Engaging farming communities in participatory learning approaches, such as farmer field schools, promotes knowledge sharing and peer-to-peer learning. Farmers learn from each other's experiences, experiment with new practices collectively, and co-create solutions that align with their specific needs and resources (Abebaw & Haile, 2013).

4. Extension services and agri-advisors: Collaborating with extension services and agri-advisors is an effective way to reach a broader audience. Extension agents act as intermediaries between educators and farmers, facilitating knowledge transfer and implementation of sustainable practices. Educators can equip extension agents with the latest information and resources to ensure accurate and consistent communication (Place *et al.,* 2019).

5. Demonstration farms and learning centers: Establishing demonstration farms and learning centers within or near farming communities provides tangible examples of sustainable practices. Farmers can visit these sites to observe successful techniques, ask questions, and receive guidance. This hands-on approach fosters experiential learning and encourages farmers to replicate what they've learned (Kahan *et al.,* 2019).

6. Digital and social media engagement: Leveraging digital platforms and social media allows educators to extend their reach beyond geographical boundaries. Educational videos, webinars, and online resources can be shared widely, providing farmers with access to valuable information. Digital platforms also facilitate interactive discussions and knowledge exchange among farming communities (Ndong *et al.,* 2020).

Measuring impact and success of agricultural education

Assessing the effectiveness of agricultural education in promoting sustainable practices requires comprehensive evaluation methods that capture both short-term learning outcomes and long-term impacts on farm productivity, environmental conservation, and economic resilience. The following assessment methods provide insights into how educational initiatives contribute to the adoption and success of sustainable farming practices.

1. Knowledge and attitude surveys: Conducting pre- and post-program surveys to assess changes in participants' knowledge and attitudes toward sustainable farming practices is a common method. Surveys can gauge learners' understanding of concepts, their perceptions of the importance of sustainable practices, and their willingness to implement them (Branson *et al.*, 2016).

2. Skill demonstrations and performance tasks: Assessing learners' practical skills through demonstrations and performance tasks allows educators to evaluate their ability to apply sustainable farming techniques. This hands-on approach measures learners' competence in implementing practices such as composting, crop rotation, or integrated pest management (Holzer *et al.*, 2017).

3. On-farm assessments: Conducting on-farm assessments involves visiting participants' farms to observe the actual implementation of sustainable practices. Educators can evaluate factors such as soil health, water management, pest control, and crop diversity. This method provides insights into the real-world application and impact of the education received (Vaughn *et al.*, 2016).

4. Case studies and reflective portfolios: Engaging learners in case studies and reflective portfolio assignments encourages them to analyze and document their experiences with sustainable practices. By documenting challenges, decisions, and outcomes, learners showcase their understanding of the practices' implications and how they navigate practical challenges (Schiavoni *et al.*, 2019).

5. Longitudinal studies: Longitudinal studies track learners' progress over an extended period, providing insights into the long-term effects of their education. This method assesses changes in knowledge, skills, and practices over time, revealing whether sustainable practices have been consistently implemented and refined (Taylor *et al.*, 2018).

6. Comparative studies: Comparative studies involve comparing the outcomes of participants who have received sustainable farming education with those who have not. By examining differences in farm productivity, environmental impact, and economic resilience between the two groups, educators can assess the direct influence of education on outcomes (Conner *et al.*, 2020).

7. Economic and environmental metrics: Assessing economic and environmental metrics such as yield improvement, reduction in chemical inputs, water usage, and carbon footprint provides tangible evidence of the impact of sustainable practices. These metrics offer quantitative insights into the broader implications of education on farm management (Takalo *et al.*, 2020).

8. Stakeholder feedback and testimonials: Collecting feedback and testimonials from participants, farmers, and stakeholders in the agricultural sector offers qualitative insights into the perceived benefits of sustainable farming education. This method highlights personal experiences, attitudes, and the perceived changes in farm practices and outcomes (Aladwani &

Almarzouq, 2021). The assessment of agricultural education's effectiveness in promoting sustainable practices requires a multi-dimensional approach that includes various assessment methods. By combining knowledge surveys, skill evaluations, on-farm assessments, case studies, longitudinal studies, comparative analyses, economic metrics, and stakeholder feedback, educators can comprehensively evaluate the impact of education on short-term learning outcomes and long-term improvements in farm productivity, environmental conservation, and economic resilience.

Challenges and Future directions:

As agricultural education strives to promote sustainable farming practices, it encounters challenges related to curriculum integration and adapting to emerging issues like climate change and technological advancements. Addressing these challenges is crucial for ensuring that educational programs remain effective, relevant, and responsive to the evolving needs of both learners and the agricultural sector.

Barriers to curriculum integration:

Challenge: Integrating sustainable farming concepts into existing curricula can be met with resistance due to factors like traditional teaching methods, limited resources, and the perceived disruption of established routines.

Future direction: To overcome this challenge, educators can collaborate with curriculum developers and academic administrators to design interdisciplinary modules that seamlessly integrate sustainable farming principles. Providing evidence of the benefits of sustainable practices and engaging stakeholders through workshops and awareness campaigns can foster support for curriculum changes.

Addressing climate change and environmental challenges:

Challenge: Climate change poses significant challenges to agriculture, requiring educators to equip learners with adaptive strategies and knowledge for mitigating its impact. Incorporating climate-smart practices into agricultural education can be complex due to the rapidly evolving nature of climate-related research.

Future direction: Agricultural education should prioritize building learners' understanding of climate change impacts on agriculture and training them in adaptive practices. Collaboration with climate experts and institutions can facilitate the inclusion of accurate and up-to-date information in curricula.

Technological advancements and digital literacy:

Challenge: The increasing integration of technology in agriculture demands that learners acquire digital literacy skills. Some learners, particularly those from rural or underserved areas, might lack access to technology and training.

Future direction: Incorporating digital literacy training within agricultural education programs prepares learners for the technology-driven future of farming. Partnerships with technology companies, organizations, and governmental initiatives can help bridge the digital divide and ensure equitable access to learning resources.

Engaging diverse learners:

Challenge: Agricultural education serves diverse learners with varying educational backgrounds, learning styles, and cultural contexts. Tailoring educational approaches to address this diversity is a persistent challenge.

Future direction: Employing flexible teaching methodologies that cater to diverse learning styles and incorporating case studies and examples from various geographic regions can enhance engagement. Educators can also collaborate with local communities to ensure that education is culturally relevant and accessible to all learners.

Encouraging lifelong learning:

Challenge: The field of agriculture is rapidly evolving, necessitating continuous learning to keep up with new technologies and practices. Encouraging learners to adopt a mindset of lifelong learning can be challenging.

Future direction: Educators can emphasize the importance of staying updated and provide resources for ongoing professional development. Integrating platforms for online learning, webinars, and workshops can empower learners to pursue lifelong learning and adapt to industry changes.

Measuring impact and outcomes:

Challenge: Evaluating the long-term impact of agricultural education on sustainable farming practices and outcomes, such as improved farm productivity and environmental conservation, can be complex.

Future direction: Incorporating robust assessment methods, including longitudinal studies, data analytics, and collaborations with research institutions, can help measure the effectiveness of education in achieving desired outcomes. Demonstrating tangible benefits will further motivate learners and stakeholders to invest in sustainable practices. Addressing challenges and adapting to future directions is essential for the success of agricultural education in promoting sustainable farming practices. By actively engaging educators, learners, stakeholders, and industry experts, educational programs can evolve to address emerging issues, incorporate technological advancements, and prepare the next generation of agricultural professionals to tackle complex challenges while fostering a sustainable and resilient food system.

Policy implications for sustainable agricultural education

Governmental policies and funding play a critical role in advancing sustainable agricultural education initiatives. Adequate financial support and strategic policies can ensure the development, implementation, and effectiveness of educational programs aimed at promoting sustainable farming practices. Governmental funding is essential for sustainable agricultural education to thrive. By allocating dedicated funds, governments can support curriculum development, teacher training, infrastructure enhancement, and the creation of practical learning resources (Eicher, 2016). This financial backing empowers educational institutions to provide comprehensive training that covers various aspects of sustainable agriculture, from soil health and water management to agroecology and integrated pest management.

Moreover, effective policies that prioritize sustainable agricultural education can catalyze systemic change. Governments can mandate the integration of sustainable farming concepts into formal education curricula across different levels of learning, ensuring that students receive essential knowledge and skills for environmentally conscious and resilient agricultural practices (Scoones & Thompson, 2011). Policy guidelines can outline specific learning outcomes, ensuring a standardized approach to sustainable farming education that permeates throughout the education system.

Advocating for the integration of sustainable farming education into broader educational agendas is essential for fostering a more environmentally conscious and sustainable agricultural sector. Policymakers can play a pivotal role in championing the cause and influencing educational institutions to adopt these practices. Policymakers can emphasize the importance of interdisciplinary approaches that link agricultural education with environmental and socio-economic considerations (Akpinar-Sposito *et al.*, 2019). By promoting collaboration between agricultural institutions and departments related to environmental sciences, policymakers facilitate a holistic understanding of sustainable practices that addresses the complex interplay between agricultural productivity, environmental conservation, and economic resilience.

Furthermore, governmental advocacy can foster partnerships between educational institutions, agricultural industries, and non-governmental organizations (Rajendram, 2014). Through collaborative efforts, educational programs can be designed to align with industry needs, ensuring that learners acquire practical skills that are relevant to modern agricultural practices and resonate with the demands of the market. Governmental policies and funding are crucial pillars for the success of sustainable agricultural education initiatives. By allocating financial resources and advocating for the integration of sustainable farming education into broader educational agendas, policymakers pave the way for the next generation of agricultural professionals to embrace sustainable practices and contribute to the global efforts towards a resilient and sustainable food system.

Conclusion:

Sustainable agriculture stands as a beacon of hope for addressing the complex challenges of feeding a growing global population while safeguarding our environment. Agricultural science education serves as a cornerstone in promoting sustainable farming practices, equipping learners with the knowledge, skills, and mindset needed to drive positive change in the agricultural sector. Through this comprehensive exploration, it becomes evident that the significance of agricultural science education transcends traditional classroom boundaries. As the world's population continues to grow, projected to reach 9.7 billion by 2050, the need for a resilient and sustainable food system becomes increasingly urgent. Sustainable farming practices not only enhance agricultural productivity but also play a crucial role in preserving our natural resources, mitigating climate change, and ensuring food security for generations to come. Educators, researchers, policymakers, and stakeholders are called upon to take proactive roles in advancing sustainable agriculture through education. Educators have the power to shape the next generation of agricultural professionals by incorporating innovative teaching methods, real-world experiences, and interdisciplinary approaches that reflect the complexity of modern farming. Researchers can contribute by generating evidence-based insights that inform curriculum development and enhance the effectiveness of educational programs.

Policymakers hold the key to creating an enabling environment that supports and prioritizes sustainable farming education. By allocating funding, advocating for policy integration, and fostering collaborations between educational institutions and industry partners, policymakers can amplify the impact of educational initiatives and ensure their alignment with broader sustainability goals. Stakeholders, including agricultural organizations, industry leaders, and non-governmental organizations, have a vital role to play in promoting sustainable farming education. Collaborative efforts can bridge the gap between academia and practical application, ensuring that learners are exposed to real-world challenges, innovative solutions, and the latest advancements in sustainable agricultural practices.

Hence, agricultural science education is not only an investment in the future; it is a catalyst for change in the present. By equipping learners with the knowledge and tools they need to navigate the complexities of sustainable agriculture, we can collectively work towards a more resilient, equitable, and sustainable food system. The call to action is clear: let us come together, share knowledge, collaborate, and empower the next generation to shape a better future for agriculture and our planet.

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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN AGRI-PRENEURSHIP, FPO AND SHG FOR SUSTAINABLE DEVELOPMENT

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Over the last three decades, significant transformations have occurred in agricultural markets worldwide. The international trade of agricultural products is undergoing a notable shift, with the local and national markets losing their former strength. Instead, the global market system for trading appears to be continuously expanding in size. The term agri-entrepreneurship is similar with entrepreneurship in agriculture and describes agribusiness establishment in agriculture and allied sector (Bairwa *et al.*, 2014). Agri-entrepreneurship in simple term can be described as sustainable, community-oriented agriculture with a direct marketing focus. Sustainable agriculture emphasizes a holistic approach considering the interconnectedness of social, economic and environmental processes. It involves combining agriculture with entrepreneurship to transform farms into agribusinesses. Agripreneurs in this field are innovators who identify markets and meet needs through various strategies.

Agripreneurship involves adding value to agricultural resources, primarily by engaging rural human resources. The end products and services arising from agripreneurial endeavours usually originate from resources in rural areas, although their consumption may extend to both urban and rural levels (Anonymous, 2015). Agricultural entrepreneurship shares similarities with other entrepreneurial forms, such as for-profit entrepreneurship, sustainable entrepreneurship, social entrepreneurship and eco-entrepreneurship while maintaining a specific focus on the agricultural sector. Rural advisory services play a vital role in supporting farmers' transition into successful agripreneurs. They provide essential information, facilitate access to markets and financial services, and offer training in managerial and functional skills. Additionally, rural advisory services have the potential to influence policies and regulations, fostering an agripreneurship-friendly environment by reducing barriers and promoting favourable societal values.

Indian Agripreneurs can learn from successful agricultural technology ventures in neighbouring developing countries. For instance, they can integrate Remote Sensing which provides bio geophysical data for agricultural crop monitoring and agro-met advisory services.

Additionally, technologies like Geographic Information System (GIS) and Internet of Things (IoT) can be employed for smart farming utilizing sensors to monitor temperature, soil moisture, light and humidity. This aids in tracking crop health, automating irrigation systems and more. By applying analytics, agripreneurs can enhance farm productivity, reduce wastage, and increase farmer's income (Mukhopadhyay and Mukhopadhyay, 2020). Furthermore, these technologies enable mapping of cropping patterns, intensity and drought assessments, leading to a better understanding of crop agronomics.

Scope in India

1. India possesses a rich variety of agro-climates, enabling the cultivation of temperate, sub-tropical, and tropical agricultural products.
2. The implementation of biotechnology in agriculture has proven to be a blessing for enhancing the production of seeds, utilizing bio-control agents and employing microbes for various industrial products.
3. The demand for agricultural inputs such as feed and fodder, inorganic fertilizers and bio-fertilizers has witnessed a rise.
4. India's extensive coastline and internal waterways offer excellent opportunities for cultivating marine and inland fish. The culture of ornamental fish is already becoming increasingly popular, driven by the rising aesthetic appreciation among Indian citizens.
5. By capitalizing on exports, India can boost its economic growth. The World Trade Organization (WTO) believes that India has significant potential to regain a prominent position in global trade for both raw and processed agricultural commodities. Currently, processing primarily occurs at the primary level, but the increasing standard of living opens up possibilities for secondary and tertiary processing of agricultural commodities presenting further opportunities for economic advancement.
6. The forest resources can be used to produce various forestry by-products.
7. The ample livestock resources present vast possibilities for the production of a wide range of items including meat, milk, dairy products, poultry and more.
8. The rise in agricultural production has led to increased employment opportunities in marketing, transportation, cold storage, warehousing facilities, credit, insurance, and logistic support services.
9. By enhancing production techniques and increasing both domestic consumption and export, the mushroom production can be improved.
10. Due to the reduction in groundwater levels and a shortage of labour for agricultural tasks such as weeding, transplanting and harvesting, there is potential for the adoption of micro-irrigation systems and labour-saving farm equipment in the upcoming years.

11. Farmers should receive encouragement and education to adopt organic farming since it holds the greatest potential in India. Compared to industrialized nations worldwide, India utilizes fewer pesticides and inorganic fertilizers, making organic farming a promising approach.
12. Beekeeping and apiary have significant potential for extensive adoption in India.

Bee Keeping Hybrid Vegetable with Bamboo Stacking

Objectives of the program

- To support potential agripreneurs by offering mentoring and internships with other start-ups providing them with practical, technical and business insights.
- To promote entrepreneurship as an attractive career option for pursuing innovative ideas among the various career choices available.
- To establish and cultivate a pipeline of agripreneurs for incubators.
- To gauge the level of awareness regarding agripreneurial activities that individuals can undertake.
- To gather information pertaining to Agripreneurship with a specific focus on India.
- To identify the issues and challenges that hinder the emergence of agripreneurs in India.
- To assess the readiness of youth to become agripreneurs given their respective circumstances.
- To discuss various correlations as strategic precursors for agribusiness development.
- To explore the phenomena and scope of the agribusiness scenario in the Indian context.

Barriers

The development of agri-entrepreneurship is crucial for enhancing production and productivity. However, in India, the rate of achieving this goal remains exceedingly low mainly due to the following reasons:

1. For the majority of farmers, agriculture primarily serves as a livelihood. Transforming their farming practices into profitable enterprises is challenging for small, uneducated landowners due to insufficient access to information, capital, technology and market connectivity.

2. Self-employed technicians require consistent support services and they should establish connections with marketing agencies, suppliers and research stations involved in modern technology development.
3. These technicians encounter various legal restrictions and obstacles while private traders involved in similar businesses tend to disregard these regulations leading to an unfair trade environment.
4. The government should consider discontinuing the free services provided by government organizations for promoting agricultural services. Many farmers, particularly politically associated leaders believe that the government is responsible for providing extension and technical advisory services. Moreover, these services do not effectively reach small farmers, especially those residing in remote areas. The notion of free services makes farmers hesitant to avail of paid services offered by local self-employed technicians.
5. Organizations are hesitant to make substantial investments and implement modern technologies which can impact profitability. Consequently, farmers lose interest in their own enterprises as well as in the initiatives led by their leaders.
6. Farmers need to be made aware of the benefits of these services as they currently lack consciousness about them.

Farmers Producer Organization (FPO)

The idea behind Farmer Producer Organizations is that agricultural product producers who are the farmers can come together to form groups. To assist in this endeavour, the Small Farmers' Agribusiness Consortium (SFAC) mandated by the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, provides support to State Governments in establishing Farmer Producer Organizations (FPOs).

Essential features of a PO: -

a. It is established "by a collective of producers engaging in either farm or non-farm activities".
b. Producers hold ownership shares within the organization.
c. It is a registered entity and holds legal recognition.
d. Its operations are aimed at benefiting the member producers.
e. It focuses on business activities associated with the primary produce or product.
f. A portion of the profit is distributed among the producers.
g. The remaining surplus is reinvested in the organization's funds to facilitate business growth.

Activities of a Producer Organization

The primary producers possess the skills and expertise in production but they often require assistance with marketing their products. The Farmer Producer Organization (PO) plays a crucial role in bridging this gap. It assumes responsibility for various activities along the value chain of the produce starting from procuring raw materials to delivering the final product to the end consumers' doorstep.

In brief, the PO could undertake the following activities:

a. Procurement of different inputs
b. Dissemination of market information
c. Dissemination of new technology and innovations
d. Facilitate finance for inputs
e. Storage of produce
f. Primary processing like cleaning, drying and grading
g. Packaging, Labelling and Standardization
h. Quality control
i. Marketing
j. Commodity exchanges
k. Product Export

Minimum and maximum number of members in a PO

The minimum number of members required for a PO depends on its legal form. For example, a Producer Company under Section 581(C) of the Indian Companies Act 1956 (same provisions retained in the 2013 Act) can be incorporated with 10 or more primary producers, and there is no maximum limit on membership. Generally, a PO needs to achieve a certain minimum scale of operation known as the break-even level to sustain its business. Studies indicate that for a sustainable operation, a PO typically requires around 700 to 1000 active producers as members. Regarding the impact on agriculture and rural development, the PO initiative can lead to improvements in productivity, production, an increase in cultivated area, expansion of irrigated land and cropping intensity. For instance, data collected from the FPO initiative may demonstrate individual farmer/producer improvements in yield, production, irrigated areas and cropping intensity. Additionally, investments in land levelling and water resources can reveal how much additional land has been brought under cultivation, highlighting the development of wasteland in the project area. The training and capacity building provided to farmers/producers can also result in enhanced produce quality during production, harvesting and storage stages. The benefits of improved quality on the commodity’s price can be assessed accordingly.

Self-Help Groups (SHG)

Self-Help Groups (SHGs) are informal gatherings of individuals who voluntarily come together to seek ways to enhance their living conditions. They can be described as self-governing peer-controlled information groups comprising individuals with similar socio-economic backgrounds and a shared desire to collectively pursue a common purpose.

Self Help Groups

Functions of Self-Help Groups

- Their objective is to enhance the functional capabilities of underprivileged and marginalized segments of society in areas related to employment and income-generating activities.
- They facilitate conflict resolution through mutual discussions and collective leadership.
- They provide collateral-free loans to individuals who typically face difficulties obtaining loans from traditional banks.
- They serve as intermediaries enabling formal banking services to reach the poor particularly in rural regions.
- They actively promote a culture of savings among the less affluent.
- They play a crucial role as a microfinance service provider for the economically disadvantage.

Need for Self Help Groups

- One of the primary factors contributing to rural poverty is the limited or lack of access to credit and financial services.
- SHGs have a significant impact on women's empowerment by helping economically disadvantaged women build social capital.
- The prevalence of robust community networks in Indian villages is now recognized as a crucial element in facilitating credit linkage in rural areas.
- SHGs play a critical role in granting credit access to the poor making them indispensable in poverty alleviation efforts.
- The Rangarajan Committee Report highlighted four major reasons for the absence of financial inclusion in India which are:

i. Inability to provide collateral security
ii. Insufficient outreach of financial institutions
iii. Fragile community network

- Financial independence through self-employment opportunities also positively affects other development factors including literacy levels, improved healthcare and better family planning.

Advantages of Self-Help Groups

- Financial Inclusion- SHGs incentivize banks to extend loans to impoverished and marginalized communities assuring them of returns.
- Social Transformation- SHGs play a role in eradicating various social issues such as dowry, alcoholism and early marriage.
- Advocacy and Pressure Groups- SHGs act as advocacy groups applying pressure on the government to address significant issues.
- Empowerment of Marginalized Voices- SHGs provide a platform for underrepresented and voiceless sections of society to express themselves.
- Advancement of Gender Equality- By empowering women, SHGs contribute to promoting genuine gender equality in the nation.
- Diversification of Livelihood/Employment Opportunities- SHGs provide vocational training to help people earn a livelihood, improve existing sources of income through tool provision and reduce dependence on agriculture.
- Enhancing Government Schemes' Efficiency- SHGs aid in the implementation and improvement of government schemes while also reducing corruption through social audits.
- Promoting Financial Literacy- SHGs encourage saving habits and foster banking literacy among rural communities.
- Impact on Healthcare and Housing- Financial inclusion facilitated by SHGs leads to improved family planning, reduced child mortality rates, enhanced maternal health, better disease management due to improved nutrition, healthcare facilities and housing.

Problems of Self-Help Groups (SHGs)

- The prevailing patriarchal mind set often hinders the participation of many women in these initiatives.
- There is a requirement to extend this concept to reach the poorest families which is not necessarily the case currently.
- The sustainability and operational quality of such groups have raised concerns.
- With approximately 1.2 lakh bank branches in rural areas compared to 6 lakh villages in the country, there is a need to further expand banking services.

- SHGs function based on mutual trust but there are concerns about the safety and security of deposits.
- Establishment of monitoring cells for SHGs across the country is necessary.

Way forward for effective Self-Help Groups

- The government must create a supportive environment to foster the growth and advancement of the SHG movement taking on the role of a facilitator and promoter.
- To achieve this, there should be an expansion of the financial infrastructure including that of NABARD through extensive IT-enabled communication and capacity-building measures in these States.
- It is essential to expand the SHG Movement to encompass Credit Deficient Areas of the Country such as Madhya Pradesh, Rajasthan and the States in the North-East.
- Efforts should be made to extend Self-Help Groups to Urban and Peri-Urban Areas, focusing on increasing income generation opportunities for the urban poor considering the rapid rise in urbanization and the prevalent financial exclusion.
- Collaboration between Commercial Banks, NABARD and the State Government is necessary to continuously innovate and design new financial products tailored to meet the specific needs of these groups.
- To ensure effective monitoring, a dedicated SHG monitoring cell should be established in every state, with direct links to district and block-level monitoring systems. This cell should gather both quantitative and qualitative information.
- Government functionaries should view the poor and marginalized as viable and responsible customers as well as potential entrepreneurs.

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BIOINFORMATICS IS AN INTERDISCIPLINARY AREA FOR VIRAL GENOME ANALYSIS AND ITS APPLICATIONS

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Abstract:

Bioinformatics composed of biology, mathematics and computer science. Bioinformatics is the application of information technology to manage biological data that helps in decoding plant genomes. The field of bioinformatics emerged as a tool to facilitate biological discoveries more than 10 years ago. With the development of Human Genome Project (HGP), the data of biology increased fabulously and marvelously. The ability to capture, manage, process, analyze and interpret data became more important than ever. Bioinformatics and computers can help scientists to solve it. Application of various bioinformatics tools in biological research enables storage, retrieval, analysis, annotation and visualization of results and promotes better understanding of biological system in fullness. This will help in animal and plant health care-based disease diagnosis and treatment. Bioinformatics and computers can help scientists to solve it. Viruses are major factors of plants and human infectious diseases. Understanding of the structure-function correlation in viruses is important for the identification of potential anti-viral inhibitors and vaccine targets. In virology research, virus-related databases and bioinformatic analysis tools are essential for discerning relationships within complex datasets about viruses and host-virus interactions. Bioinformatic analyses on viruses include the identification of open reading frames, gene prediction, homology searching, sequence alignment, and motif and epitope recognition. The predictions of features such as transmembrane domains, glycosylation sites, and protein secondary and tertiary structure are important for analyzing the structure-function relationship of proteins encoded in viral genomes. Since the discovery of computers, bioinformatics and computational biology have been instrumental in a wide range of discoveries in virology. These include early mathematical models of virus-host interaction, and more recently the analysis of viral nucleotide and protein sequences to track their function, epidemiology, and evolution.

Keywords: Annotation, computational biology, bioinformatics, disease diagnosis, homology searching

Introduction:

Term Bioinformatics was coined by Paulien Hogeweg and Ben Hesper in 1970 as the study of informatic processes in biotic systems. Bioinformatics deals with computational management and analysis of biological information (genes, genomes, proteins, cells, ecological systems, medical information, robots, artificial intelligence etc. The National Center for Biotechnology Information (NCBI, 2001) defined Bioinformatics as the field of science in which biology, computer science, and information technology merge into a single discipline. Fredj Tekaia at the Institute Pasteur defines bioinformatics the mathematical, statistical and computing methods that aim to solve biological problems using DNA and amino acid sequences and related information. Since the sequencing of the first complete microbial genome of *Haemophilus influenzae* in 1995 hundreds of microbial genomes have been sequenced and archived for public research in Gene Bank. The vast amount of data generated by genome sequencing projects is becoming unmanageable. Bioinformatics has silently filled in the role of cost-effective data analysis. Bioinformatics analysis has enhanced our understandings about the genome structure and the microorganism restructuring process. Bioinformatics has emerged as an essential field of science that is facilitating biological discoveries since more than a decade. Without the usage of bioinformatics tools, it is merely impossible to capture, manage process, analyses and interpret the huge amounts data that is available especially after whole genome sequencing projects. The sequencing of the genomes of plants and animals will have enormous benefits for the agricultural community. Bioinformatics tools can be used to search for the genes within these genomes and to elucidate their functions. This specific genetic knowledge could then be used to produce stronger, drought, disease and insect resistant crops and improve the quality. In agriculture it helps in the insect resistance, improve nutritional quality, rational plant improvement, waste cleanup, climate change studies, and development of drought resistance varieties (Dahiya and Lata, 2017) and in addition to this it also plays an important role in biotechnology, antibiotic resistance, and forensic analysis of microbes, comparative studies, evolutionary studies and veterinary Sciences.

Bioinformatics term and definitions:

Term was given by- **Pavlien Hogewag and Ben Hesper in 1970.**

Bio + Informatic = Biological system + Information Technology

- Bioinformatics is an interdisciplinary area of the science composed of biology, mathematics and computer science.

or

- Bioinformatics deals with computational management and analysis of biological information (genes, genomes, proteins, cells, ecological systems, médical information, robots, artificiel intelligence etc.

or

- Bioinformatics develops algorithms and suitable data analysis tools to infer the information and make discoveries.

History of bioinformatics:

1865: Father of Genetics: Gregor Mendel discovers the concept of genetic inheritance

1930: Electrophoresis introduced

1953: Watson and Crick suggest double-helix model for DNA

1955: Bovine Insulin is first protein to be sequenced

1970: the term Bioinformatics first used

1984: FASTP algorithm program published

1990: BLAST program published

1994: PRINTS database published

1995: First bacterial genomes sequenced

2000: EMOTIF database released

Technology and bioinformatics drive discoveries

The past decades have been characterized by technological innovations that revolutionized the way we do science, ranging from the development of computers and the internet, to high-throughput measurement technologies including DNA sequencing, mass spectrometry, and imaging. New fields were built based upon these developments, including bioinformatics, machine learning, and omics. These advances have expanded the scope in all scientific fields, not least in virology. One of the most profound impacts is a new view of the virosphere that is one of an unparalleled diversity. To illustrate, the number of recognized deep viral taxonomic groups has been greatly expanded and the International Committee for Taxonomy of Viruses (ICTV) has recently approved an expansion of the resolution of the viral taxonomy to 15 ranks: realm, sub-realm, kingdom, subkingdom, phylum, subphylum, class, subclass, order, suborder, family, subfamily, genus, subgenus, and species.

Bioinformatic analyses of omics and other biological datasets depend on specialized computational tools. The development of these tools begins with basic analyses that are then incrementally used to create more complex applications. Examples of basic applications include software to validate the data derived from next-generation sequencing machines, build alignments of gene or protein sequences, and perform statistical tests. Higher-level analyses may include pipelines for metagenomic analysis, genome annotation, or genotype-phenotype association. Taken together, bioinformatics is arguably one of the subdisciplines in the life sciences with the broadest applicability. When calculated as the amount of computer time allotted to computational analyses, the largest consumer in virology is the analysis of omics datasets. Omics analyses are characterized as high-throughput, untargeted, and generally quantitative, and their application opens the door to systems level analysis of viruses and their effects on their hosts. For example, comparative genomics allows thousands of viruses to be analyzed, identifying important viral genes, their functions, and their evolution; metagenomics allows viruses to be discovered and identified with high throughput; and phylogenetics and phylogenomic allow new viral taxonomic groups to be identified.

Why bioinformatics is important?

- Bioinformatic tools has their ability to identify plant- and animal-infecting viruses while distinguishing from the host genetic material. We discovered that many of the current generation of virus-detection pipelines are not adequate for this task, being out performed by more generic classification tools.
- Need to incorporate computers into the research process.
- With the advent of new tools and databases in molecular biology we are now enable to carry out the research not only at genome level but also at proteome, transcriptome and metabolome levels.
- The intelligent and efficient storage of huge amount of data generated, and to provide easy and reliable access to this data and reduce time and cost in molecular studies.
- The ultimate goal of bioinformatics is to uncover the wealth of biological information hidden in the mass of sequence, structure, literature and other biological data.
- The field of biosecurity has greatly benefited from the widespread adoption of high throughput sequencing technologies, for its ability to deeply query plant and animal samples for pathogens for which no tests exist.

Components of bioinformatics

1. Technology and computing power

Technology is the collection of techniques, skills, methods, and processes applied to make life easier. Technology can be the knowledge of techniques, processes, computing power.

2. Creation of databases

This involves the organizing, storage and management the biological data sets (viral genome). The databases are accessible to researchers to know the existing information and submit new entries, e.g., protein sequence data bank for molecular structure. Databases will be of no use until analyzed.

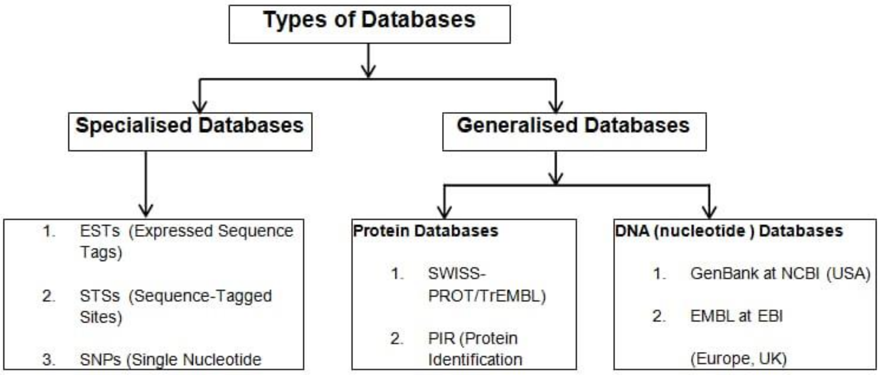

Fig. 1: Types of Databases

3. Development of algorithms and statistics

This involves the development of tools and resources to determine the relationship among the members of large data sets e.g., comparison of protein sequence, DNA, RNA sequences data with the already existing sequences.

4. Analysis of data and interpretation

The appropriate use of components to analyze the data and interpret the results in a biologically meaningful manner. This includes DNA, RNA and protein sequences, protein structure, gene expression profiles.

5. Computational Biology

Broadly speaking, computational biology is the application of computer science, statistics, and mathematics to problems in biology. Computational biology spans a wide range of fields within biology, including genomics/genetics, cell biology, biochemistry, and evolution.

6. Molecular biology

Molecular biology is the study of biology at a molecular level. The field overlaps with other areas of biology and chemistry, particularly genetics and biochemistry. Molecular biology chiefly concerns itself with understanding the interactions between the various systems of a cell, including the interrelationship of DNA, RNA and protein synthesis and learning how these interactions are regulated.

Molecular biology is the study of molecular underpinnings of the process of replication, transcription and translation of the viral genetic material. The central dogma of molecular biology where genetic material is transcribed into RNA and then translated into protein, despite being an oversimplified picture of molecular biology, still provides a good starting point for understanding the field.

7. Genomics

Genomics is an interdisciplinary field of science within the field of molecular biology. A genome is a complete set of DNAs within a single cell of an organism.

Genomics aims at the collective characterization and quantification of genes, which direct the production of proteins with the assistance of enzymes and messenger molecules. Genomics also involves the sequencing and analysis of genomes.

In contrast to genetics, which refers to the study of individual genes and their roles in inheritance, genomics uses high throughput DNA sequencing and bioinformatics to assemble, and analyze the function and structure of entire viral genomes.

8. Computer sciences

The study of the theory, experimentation, and engineering that form the basis for the design and use of computers. It is the scientific and practical approach to computation and its applications and the systematic study of the feasibility, structure, expression, and mechanization of the methodical procedures (or algorithms) that underlie the acquisition, representation, processing, storage, communication of, and access to information. Bioinformatics brings together large data bases of biological information and computational techniques of analysis.

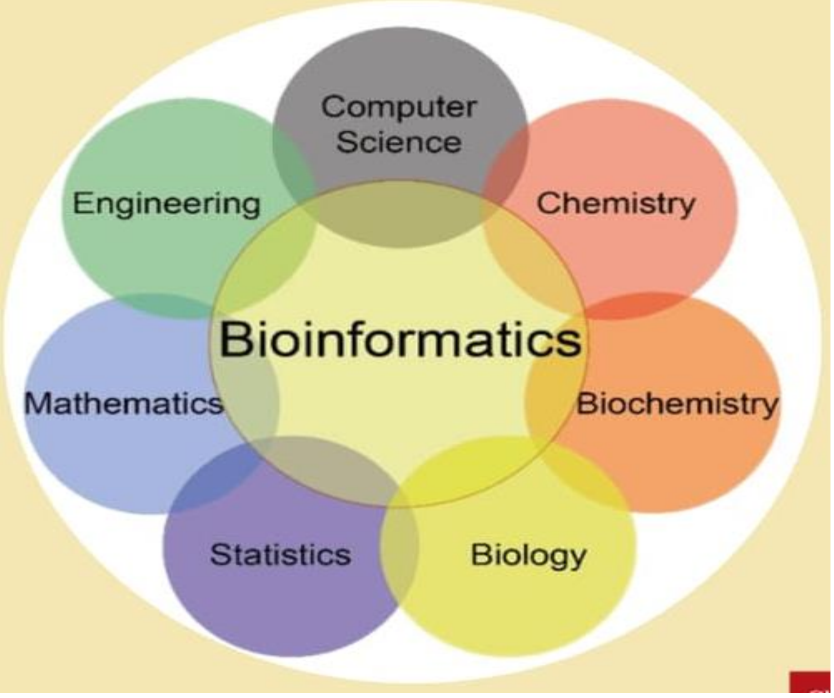

Fig. 2: Components of Bioinformatics

What is done in bioinformatics?

- The development of new algorithms and statistics with which to assess relationships among members of large viral data sets.

- The analysis and interpretation of various types of data including nucleotide and amino acid sequences, protein domains, and protein structures of viruses.
- The development and implementation of tools that enable efficient access and management of different types of information.

How do we use bioinformatics?

- Store/retrieve biological information (databases)
- Retrieve/compare gene sequences
- Predict function of unknown genes/proteins
- Search for previously known functions of a gene
- Compare data with other researchers
- Compile/distribute data for other researchers

Software and tools for diagnostics

- Software tools for bioinformatics range from simple command-line tools, to more complex graphical programs and standalone web services available from various bioinformatics companies or public institutions.
- The computational biology tool best-known among biologists is probably BLAST, an algorithm for determining the similarity of arbitrary sequences against other sequences, possibly from curated databases of protein or DNA sequences. BLAST is one of a number of generally available programs for doing sequence alignment.
- The NCBI provides a popular web-based implementation that searches their databases.

Viral infections can form a significant burden not only for human health but also for the health livestock and plants. The direct detection of viruses in clinical and other samples include microscopy, antigen detection such as ELISA, and molecular detection of the viral genomic material by PCR. Popular molecular diagnostic techniques including qPCR or RT-qPCR also allow quantification of viral loads. While these techniques are highly sensitive for the detection of specific viruses in a sample, they can only identify viral sequences that match a pre-defined search image that matches the designed PCR primers. Thus, these established diagnostic tests frequently yield negative results and no virus is detected. This can be either because an uncommon variant of a known pathogen is present in the sample, or because a novel virus is the causative agent of the disease. Notably, the difference between these two possibilities is continuous, reflecting increasing evolutionary distances along the viral phylogeny.

Bioinformatic approaches allow PCR panels to be designed that capture an increasingly diverse array of viruses, but these assays will always remain limited to detecting viruses within a known range, and cannot extrapolate to identify completely novel ones. This may be resolved by untargeted (shotgun) sequencing of isolated viruses or complete sample DNA (metagenomics). Variants of known viruses may be detected by aligning the reads derived from the sample to the reference sequence of the known virus that was originally used for designing the primers. If enough high-quality reads span the regions where the primer sequences should anneal with the target, specialized variant detection tools can call the variant with a high degree of confidence, and new PCR primers can be designed to capture them. For example, a recent PCR-based investigation of the widespread human gut-associated bacteriophage crass phage designed globally applicable primers by screening an alignment of sequencing reads from a range of publicly available metagenomes and identifying highly variable regions of the appropriate size (1000–1400 nucleotides) that were flanked by conserved regions which could be targeted by primers, and were present in ≥90% of all metagenomic samples (<10% gaps).

BLAST (Basic Local Alignment Search Tool): A Bioinformatic Technology

- Basic Local Alignment Search Tool is an algorithm for comparing biological sequences information, such as amino acid sequence of different proteins or the nucleotides of DNA sequences.
- BLAST is used to identify library sequences that resembles the query sequences.
- The BLAST program was designed by Eugene Myers, Stephen Altschul, Warren Gish, David J. Lipman and Webb Miller at the NIH and was published in *J. Mol. Biol.* in 1990.
- BLAST is a tool for alignment of sequences. e.g., To identify the unknown gene (query sequences) in the mouse, the scientist will perform a BLAST search of the human genome (library sequences) to see whether the human carrying the similar gene or not.
- BLAST was originally developed by NCBI (National Center for Biotechnology Information) to map annotations from one organism to another

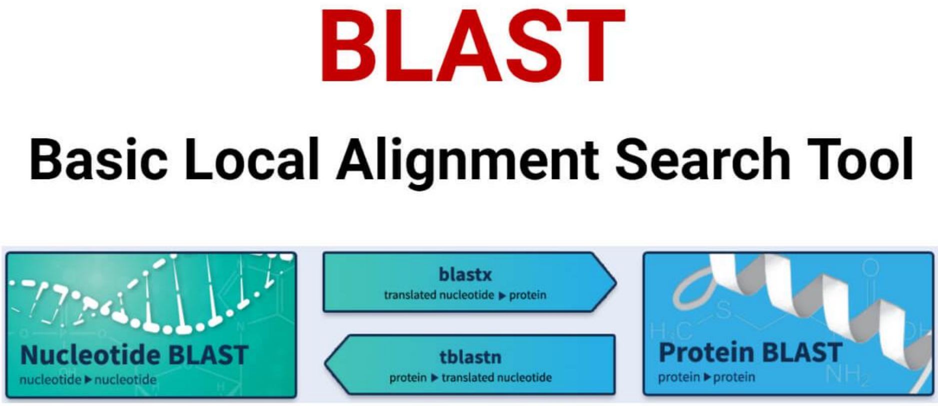

Fig. 3 BLAST (Basic Local Alignment Search Tool)

Kinds of BLASTs:

1. Nucleotide 6-frame translation-protein (blastx): This program compares the six-frame conceptual translation products of a nucleotide query sequence (both strands) against a protein sequence database.

2. Nucleotide 6-frame translation-nucleotide 6-frame translation (tblastx): This program is the slowest of the BLAST family. The purpose of tblastx is to find very distant relationships between nucleotide sequences.

3. Protein-nucleotide 6-frame translation (tblastn): This program compares a protein query against the all six reading frames of a nucleotide sequence database.

4. BLASTn: Compare a DNA query sequence against a DNA database, allowing for gaps.

5. BLASTp: Compare a protein query sequence against a protein database, allowing for gaps.

Process of BLAST:

- ❖ BLAST works through use of heuristic algorithm. Heuristic algorithm, is an algorithm that is able to produce an acceptable solution to a problem in many practical scenarios.
- ❖ Heuristics are typically used when there is no known method to find an optimal solution, under the given constraint.
- ❖ Using a heuristic method, BLAST finds homologous sequences, not by comparing either sequence in its entirety, but rather by locating short matches between the two sequences. This process of finding initial words is called seeding.
- ❖ While attempting to find homology in sequences, sets of common letters, known as words. For example, the sequences contain the following stretch of letters, GLKFA. If a BLASTp was being conducted under default conditions, the word size would be 3 letters.
- ❖ In this case, using the given stretch of letters, the searched words would be GLK, LKF, and KFA. The heuristic algorithm of BLAST locates all common words between the sequences of interest (query) and the hit sequences (sequences from database).

BLAST can be used for several purpose:

- ❖ **Identifying species:** With the use of BLAST, you can possibly correctly identify a species and/or find homologous species. This can be useful, for example, when you are working with a DNA sequence from an unknown species.
- ❖ **Locating domains:** When working with a protein sequence you can input it into BLAST, to locate known domains within the sequence of interest.
- ❖ **Establishing phylogeny:** Using the results received through BLAST, you can create a phylogenetic tree using the BLAST web-page.

- **DNA mapping:** When working with a known species, and looking to sequence a gene at an unknown location, BLAST can compare the chromosomal position of the sequence of interest, to relevant sequences in the database(s).
- **Comparison:** When working with genes, BLAST can locate common genes in two related species, and can be us.

Steps of bioinformatics:

1. Collection of biomolecules e.g., DNA, RNA, PROTEIN
2. Experimental technology e.g., NGS, DNA Micro-array
3. Molecular data sequencing, data reads, expression, intensity values.
4. Analytical and statistical work flow e.g., Alignment gene prediction
5. Functional interpretation- Network pathway
6. Data visualization e.g., Graphs, charts, head-maps and network.

Applications of bioinformatics:

- The genomes and the tools used to mine data, provide unique sequence signatures that may be used to populate microarray chips for surveillance and diagnostics or to develop specific polymerase chain reaction (PCR) assays.
- A different application is realized in using these approaches to understand in greater detail the viruses that are used in biomedical and biotechnological processes.
- Genomics and bioinformatics allow for a rational approach to designing appropriate and safe vectors.
- Searching restriction sites
- Protein-protein interaction
- Epitope designing
- Gene expression
- Whole genome analysis
- Drug designing
- Evolutionary and phylogenetic studies

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EDIBLE INSECTS AS A SUSTAINABLE FOOD SOURCE

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Abstract:

Consumption of edible insects is known as entomophagy. Insects are a common element of the diets of about 3000 ethnic groups, mostly in nations in Africa, Asia, and Latin America. Depending on the species and processing technique, they can be eaten at several life stages including eggs, nymphs, and adults. Entomophagy is considered a potent dietary practice to replace animal protein due to its highly nutritious, protein-rich, and environmentally sustainable nature. Beneficial effects of edible insects on health have been reported in numerous studies, and they possess several health-promoting properties such as antidiabetic, antioxidative, antiobesity, and anticancer activity, along with gastro-intestinal health benefits.

Keywords: Entomophagy, protein, antidiabetic, antioxidative, antiobesity

Introduction:

According to the most recognized definition established by the World Food Summit in 1996, food security is a "situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preference for an active and healthy life". The definition is based on four pillars: availability, stability, access and utilization. The first dimension relates to the availability of sufficient food, and therefore, it refers to the overall ability of the agricultural system to meet food demand. The stability dimension relates to individuals who are at high risk of temporarily or permanently losing their access to the resources needed to consume adequate food. The third dimension, access, covers access by individuals to adequate resources to acquire appropriate foods for a nutritious diet. Thus, a key element is the purchasing power of consumers and the evolution of real incomes and food prices. Finally, utilization encompasses all food safety and quality aspects of nutrition.

Beyond the food crisis that relaunched the issue of global food security, many factors may aggravate the balance between global food supply and demand in the coming decades, thus affecting the level of food insecurity. Population growth, urbanization, dietary demand and Westernization of food styles, overexploitation and depletion of natural resources, climate change and land use for biofuel production are just some of the crucial factors that may jeopardize food security goals in the coming years.

In particular, the dynamics of growth in the global demand for proteins, and especially animal proteins, have directed the attention of researchers to the identification of new protein sources that can meet the growing global demand. Categories of the alternative sources of animal proteins include: cultured meats, produced in vitro; plant-based meat analogs, manufactured using plants-extracted proteins; single-cell proteins (SCP), characterized by a microbial origin; earthworms and edible insects, which exhibit a high feed/meat conversion rate. Among the alternative sources of animal proteins mentioned so far, edible insects represent the option that most closely meets the necessary requirements for food security.

Background

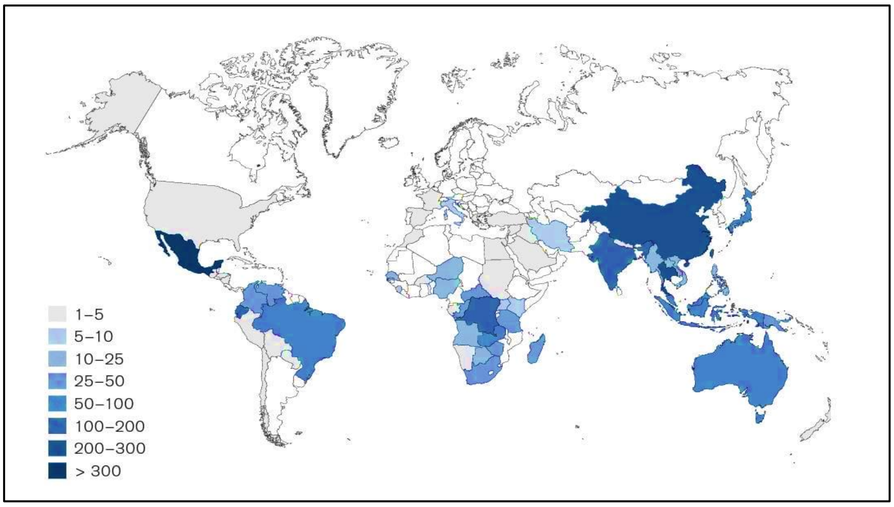
- Cave paintings in Altamira, North Spain dated from 3000 to 9000 BC depicted the collection of edible insects and wild bee nests.
- Aristotle (384-322BC) in his 'Historia animalium' quoted 'The larva of the cicada on attaining full size becomes tasty before the husk is broken (i.e. before the last moult). Among the adults at first the males are better to eat, but after copulation the females, which are then full of white eggs'
- Aldrovandi in his 'De Animalibus Insectis Libri Septem' (1602) stated that 'ants are eaten in certain parts of India'.
- These evidences suggest that evolutionary ancestors of *Homo sapiens* were entomophagus.

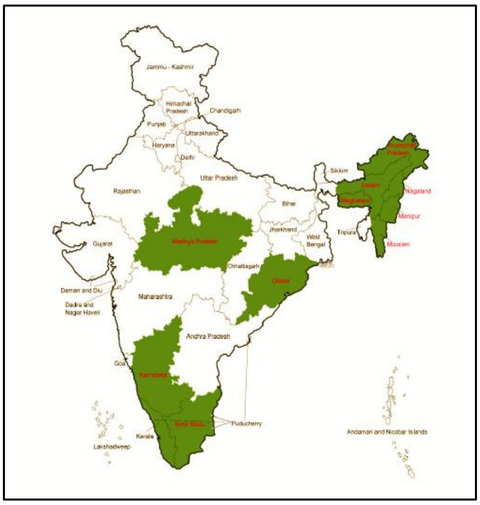
Food demand is increasing with fast and rapid growing population. FAO estimates that the world needs to increase its food production by 2050 in order to serve a global population of 9 billion.

Species used as food

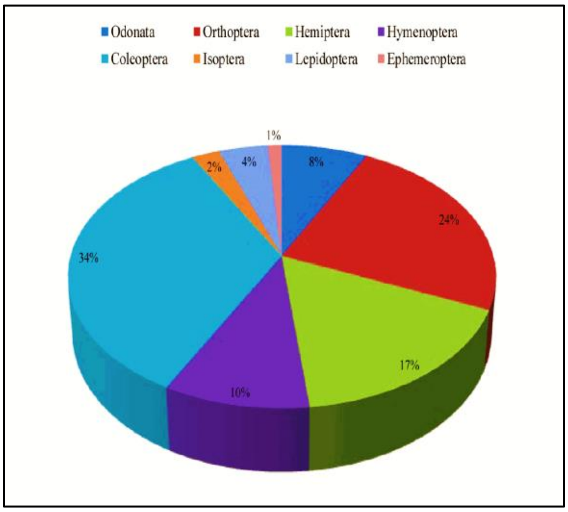
Globally, the most common insects consumed are beetles (Coleoptera) (31 percent). This is not surprising given that the group contains about 40 percent of all known insect species. The consumption of caterpillars (Lepidoptera), is estimated at 18 percent. Bees, wasps and ants (Hymenoptera) come in third at 14 percent. Following these are grasshoppers, locusts and crickets (Orthoptera) (13 percent); cicadas, leafhoppers, planthoppers, scale insects and true bugs (Hemiptera) (10 percent); termites (Isoptera) (3 percent); dragonflies (Odonata) (3 percent); flies (Diptera) (2 percent); and other orders (5 percent).

Providing definitive figures on the number of edible insect species worldwide is difficult for several reasons. First, a layperson is unlikely to describe an insect by its Linnaean nomenclature, making official estimates difficult. Many cultures of more than one vernacular name – By using only Latin names and correcting for synonyms, Yde Jongema of WUR conducted a worldwide inventory using the literature, including from Western countries and temperate regions, and listed the number of edible insect species globally as in the figure Jongema (2012).





Insect consumption in different states of India



Order wise distribution of edible insects in India

Insects that are taken as food is considered and a consolidated inventory on what is known to date on the edible insects from various parts of India is presented in the figures. total of about 255 species of edible insects so far recorded from different parts of India. Among the ethnic people of India, the tribes of Arunachal Pradesh outreaches in terms of number of edible insects taken as food, a total of about 158 species, this is followed by in Manipur, Assam and Nagaland (16 to 40 insect species) and to a lesser extent in Meghalaya. However, in Kerala, Madhya Pradesh, Odisha Tamil Nadu and Karnataka, this number limits only six insect species.

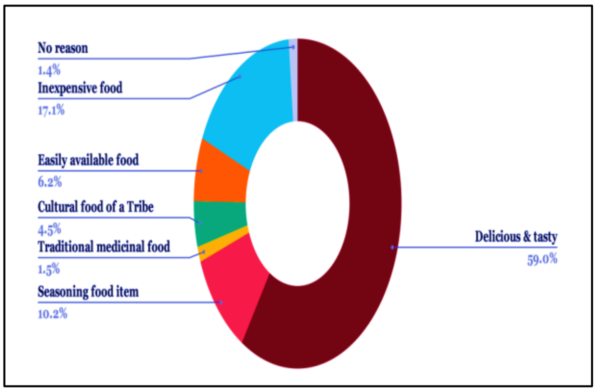
None the less, the consumption of coleopteran species was highest constituting about 34%; next come Orthoptera (24%); Hemiptera (17%); Hymanoptera (10%); Odonata (8%); Lepidoptera (4%); Isoptera (2%) and the least was Ephimeroptera (1%) (Chakravorty, 2014).

In India, biodiversity had been existing since ancient times due to harmonious coexistence between tribal communities and natural resources. Despite this fact, systematic survey on edible insects has not been undertaken by any government agency. For edible insects, indigenous communities select the proper processing methods as they have experience for generations, and try to improve their daily food.

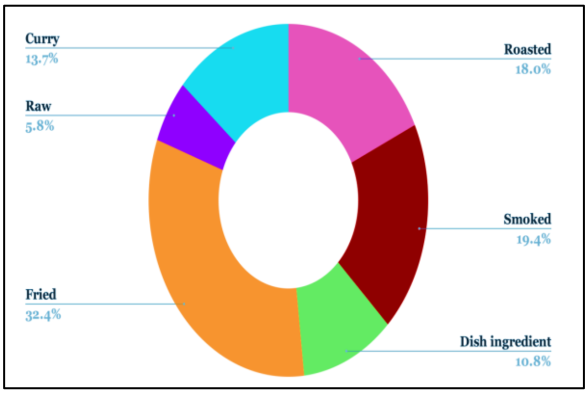
Major edible insects documented from India (Gahukar, 2018):

Method of Processing	Insect species	Order: Family	Insect life stage(s)
Baked	*Apis cerana indica*	Hymenoptera: Apidae	Egg, larva, pupa
	Antheraea assamensis	Lepidoptera: Saturnidae	Pupa
	Oecophylla smaragdina	Hymenoptera: Formicidae	Egg, adult
	Rhynchophorus phoenicis	Coleoptera: Curculionidae	Larva
	Rhynchophorus ferrugineus	Coleoptera: Curculionidae	Larva
Cooked	*Pentatomid* sp.	Hemiptera: Pentatomidae	Adult
Cooked + baked	*Polistes stigmata*	Hymenoptera: Vespidae	Egg, larva, pupa
	Samia ricini	Lepidoptera: Saturnidae	Larva, pupa
	Myrmica rubra	Hymenoptera: Formicidae	Larva, pupa
Dry/deep fried	*Reticulitermes flavipes*	Isoptera: Rhinotermitidae	Adult
	Dihammu scervinus	Coleoptera: Cerambycidae	Larva
	Meligethes aeneus	Coleoptera: Nitidulidae	Larva
	Batocera rufomaculata	Coleoptera: Cerambycidae	Larva
	Okanagan sp.	Diptera: Asilidae	Adult
Dry/deep fried + baked	*Megasoma elephas*	Coleoptera: Scarabaeidae	Larva
	Apis dorsata	Hymenoptera: Apidae	Larva, pupa
	Apis cerana indica	Hymenoptera: Apidae	Larva, pupa
	Apis florea	Hymenoptera: Apidae	Larva, pupa
Deep fried + roasted	*Mantis religiosa*	Orthoptera: Mantidae	Nymph, adult
	Melanopus sp.	Orthoptera: Acrididae	Adult
Raw/fresh	*Aeshna mixta*	Odonata: Aeshnidae	Nymph, adult
	Neurothemis fluctuans	Odonata: Libellulidae	Nymph, adult

	Apis dorsata	Hymenoptera: Apidae	Larva (hive)
	Apis cerana indica	Hymenoptera: Apidae	Larva (hive)
	Vespa mandarinia	Hymenoptera: Vespidae	Larva
Roasted	*Schizodactylus monstrosus*	Orthoptera: Gryllidae	Nymph, adult
	Gryllus campestris	Orthoptera: Gryllidae	Nymph, adult
	Gryllotalpa africana	Orthoptera: Gryllotalpidae	Nymph, adult
	Odontolabis cuvera	Coleoptera: Lucanidae	Adult
	Lucanus elsphus	Coleoptera: Lucanidae	Adult
	Cyrtotrachelus buqueti	Coleoptera: Curculionidae	Larva
	Eurytrachelus titan	Coleoptera: Dynastidae	Adult
	Libellula carolina	Odonata: Libellulidae	Adult
	Schistocerca gregaria	Orthoptera: Acrididae	Nymph, adult
	Belostoma indicus	Hemiptera: Belostomatidae	Adult
	Vespa tropica	Hymenoptera: Vespidae	Larva
	Vespa bicolor	Hymenoptera: Vespidae	Larva
	Polistes sp.	Hymenoptera: Vespidae	Larva



Different modes of eating insects



Different reasons for practicing entomophagy

Insects used as feed

Hazarika *et al.*, (2020) studied the pattern of entomophagy and the attitude towards insect-eating of ethnic people in Manas National Park, a UNESCO Natural World Heritage Site, located in Assam, India. They reported that the reasons for practicing entomophagy are as the insects were found to be delicious and tasty (59%), inexpensive (17.1%), as seasonal food item (10.2%), easily available (6.2%), as cultural food (4.5%), followed by traditional medicinal food (1.5%) and for no reason (1.4%). The different modes of eating insects recorded were fried

(32.4%), smoked (19.4%), roasted (18%), curry (13.7%), as dish ingredient (10.8%) and consumed as raw (5.8%).

Insects used in livestock feed

Insect species	Order	Percentage
Musca domestica	Diptera	34
Bombyx mori	Lepidoptera	29
Hermetia illuscens	Diptera	13
Tenebrio molitor	Coleoptera	9

Change and innovation are required in many livestock production systems if they are to meet the present and future demands for animal products. In this context, research on and commercial implementation of new feeds (especially those rich in protein) for animal feeding is needed for sustainable animal production. Currently, there is great interest in the role of insects in animal feeding.

The nutritional potential of up to 24 different species of insects belonging to 6 different orders (Blattodea, Coleoptera, Diptera, Isoptera, Lepidoptera, and Orthoptera) have been exploited majorly. However, most publications have tested species from the Diptera (48%) and Lepidoptera (29%) orders. However, the insects used for livestock and aquaculture varies as in the table listed below (Sanchez *et al.,* 2016).

Insects used in aquaculture feed

Insect species	Order	Percentage
Musca domestica	Diptera	43
Bombyx mori	Lepidoptera	17
Antheraea assamensis	Lepidoptera	6
Hermetia illuscens	Diptera	6

Benefits:

Health

- Insects are healthy, nutritious alternatives to mainstream staples such as chicken, pork, beef and even fish (from ocean catch).
- Many insects are rich in protein and good fats and high in calcium, iron and zinc. Insects already form a traditional part of many regional and national diets.

Insect	Energy (kcal/100g)	Protein (g/100g)	Fat (g/100g)	Vit B2 (mg/100g)	Na (mg/100g)	Ca (mg/100g)
Acheta domesticus (A)	153	20.5	5.06	3.41	163-178	99.6
Acheta domesticus (L)	137.5	15.4-17.5	4.4-7.9	1.66	110	36.6
Tenebrio molitor (A)	178	24.13	6.14	0.85	66	24.2
Bombyx mori (L)	171.27 - 229	17.9 - 23.1	4.26 – 5.0	0.94	47.5	49.8 – 72.2
Mutton leg	196.56	15.12	15.12	0.18	65.5	8.4
Chicken breast	98	21.5	1.3	0.15	55	5.0
Chicken drumstick	125	17.8	6	0.25	91	8.0

(Source: Orkusz, 2021)

Stull *et al*. (2018) evaluated the effects of consuming 25 grams/day whole cricket powder on gut microbiota which revealed that cricket consumption is tolerable and non-toxic at the studied dose and it supported growth of the probiotic bacterium, *Bifidobacterium animalis*, which increased 5.7-fold and also associated with reduced plasma TNF-α. As feed, Gooya *et al.*, 2020 studied the effect of *Tenebrio molitor* larvae on growth performance of broiler chickens and reported that protein replacement with 2.5% or 5% TM meal in the broilers diet improved body weight gain (BWG) and feed conversion ratio (FCR) in the period of starter.

- The nutritional values of edible insects are highly variable, not least because of the wide variety of species. Even within the same group of edible insect species, values may differ depending on the metamorphic stage of the insect, their habitat and diet etc. As reported by Cerreta *et al*. (2021) nutrient profile of four edible species of cockroaches *viz*., *Blaberus giganteus*, *Blaptica dubia*, *Blatta lateralis* and *Gromphadorhina portentosa* varied and among the sex also the nutritional composition was found to be different.
- Like most foods, preparation and processing methods (e.g. drying, boiling or frying) applied before consumption will also influence nutritional composition.

Environmental:

- Insects promoted as food emit considerably fewer greenhouse gases (GHGs) than most livestock (methane, for instance, is produced by only a few insect groups, such as termites and cockroaches).

- Insect rearing is not necessarily a land-based activity and does not require land clearing to expand production. Feed is the major requirement for land.
- The ammonia emissions associated with insect rearing are also far lower than those linked to conventional livestock, such as pigs.
- Because they are cold-blooded, insects are very efficient at converting feed into protein (crickets, for example, need 12 times less feed than cattle, four times less feed than sheep, and half as much feed as pigs and broiler chickens to produce the same amount of protein). Insects can be fed on organic waste streams.

Efficiencies of production of conventional meat and crickets (Source: Van Huis, 2013)

	Cricket	**Poultry**	**Pork**	**Beef**
Feed conversion ratio (Kilogram feed : Kilogram live weight)	1.7	2.5	5	10
Edible portion	80	55	55	40
Feed (Kilogram : Kilogram edible weight)	2.1	4.5	9.1	25

Water footprint (Source: Miglietta *et al.*, 2015)

Food	**Water foot print per unit of nutritional value (L/g protein)**
Mealworms	23
Pork	57
Chicken	34
Beef	112

Global warming potential and land requirement (Source: Oonincx and De Boer (2012)

Food	**Global warming potential (CO_2-eq)**	**Land use area (Area m^2/kg protein)**
Mealworms	14	18
Pork	27	55
Chicken	19	47
Beef	88	201

Livelihoods (economic and social factors):

- Insect harvesting/rearing is a low-tech, low-capital investment option that offers entry even to the poorest sections of society, such as women and the landless.
- Minilivestock offer livelihood opportunities for both urban and rural people because of their nutritional composition, accessibility, simple rearing techniques and quick growth rates, insects can offer a cheap and efficient opportunity to counter nutritional insecurity by providing emergency food and by improving livelihoods and the quality of traditional diets among vulnerable people.
- Insect rearing can be low-tech or very sophisticated, depending on the level of investment.

Edible insect products

Types of edible insect products available globally are

1. **Foods**

Flours, breads, chips, alternative meats, pastas, noodles, sausages, burger patties etc.

2. **Confectionary**

Candies, Chocolates, Ice creams, Cookies etc.

3. **Beverages**

Beers, milks, milkshakes, soft drinks, spirits and alcohol, protein enriched/ fortified drinks etc.

4. **Others**

Bitters, butters, oils, spices and seasonings

Insect production methods

Edible insects can be obtained in three ways

- Wild harvesting
- Semi domestication
- Farming

However, when the global list of known edible insects was assessed as to whether they are wild harvested, semi-domesticated, or farmed, the vast majority of species are wild harvested. The results indicated that 92% of known edible insect species are wild harvested, 6% are semi-domesticated and only 2% are farmed. Yen (2015). Out of 92 % wild harvested, 88 % are terrestrial insects and remaining are aquatic.

Wild harvesting:

The method of collecting edible insects from wild or its natural habitats.

The benefits of harvesting plant pests are

(1) increased plant food productivity

(2) an additional food resource (the insects) and

(3) health and environmental benefits of reduced insecticide use.

Wild harvesting of some common edible insects (Ishara *et al.*, 2022)

Insect species	**Harvesting technique**
Termites	Light trapping
House cricket	Trapping and Handpicking
Palm weevil	Handpicking
Beetle	Handpicking
Locust	Handpicking
Red palm weevil	Handpicking
Rhinoceros beetle	Handpicking
Caterpillar	Handpicking
Mole cricket	Handpicking
Grasshopper	Light trapping & handpicking
Honeybee	Collecting honeycomb from hive

Wasp brood collection from the tree trunk by smoking it

Bamboo grubs collected from infested bamboo plants

Stink bugs collected in locally woven nylon bags

Odonata adult collection using bamboo stick and local glue

Aquatic beetles collected by using a locally made bamboo basket

Traditional harvesting methods of edible insects in Arunachal Pradesh (Chakravorty, 2018)

Semi domestication

The captive state of an insect in which its living conditions are controlled by humans is called semi-domestication. It may also enable the manipulation of an edible insect's habitat at a small or large scale, such as the insects' behaviour and availability throughout the year. This is termed semi-cultivation, as it resembles cultivating – a process that promotes the growth (or quality) of an organism through the use of labour and skill. Semi-cultivation rarely involves the tending of insects. Semi-cultivated insects are available in the wild and are generally not grown in captivity (although some may be captive during part of their development). The manipulations intended for producing edible insects are therefore useful as first steps towards a more controlled production. Semi-cultivation has many benefits, not least of which is ensuring the availability and predictability of edible insects. The activities surrounding semi-cultivation have the potential to contribute to both edible insect habitat conservation and food security

Kiewhou *et al*. (2022) studied the traditional rearing technique of the edible Asian giant hornet *Vespa mandarinia* and reported that traditional rearing techniques and hornet semidomestication can lead to an increase in the production of hornets which then not only serve as an additional and valuable protein source, but will also help in safeguarding hornet diversity.

A hollow pit of 60-75 cm for new rerearing site

Comb collected from wild is tied onto a strong wood and hanged downward

Bamboo slices placed horizontally to maintain strong foundation for the hornets to move

Large hornet comb harvested after successful rearing

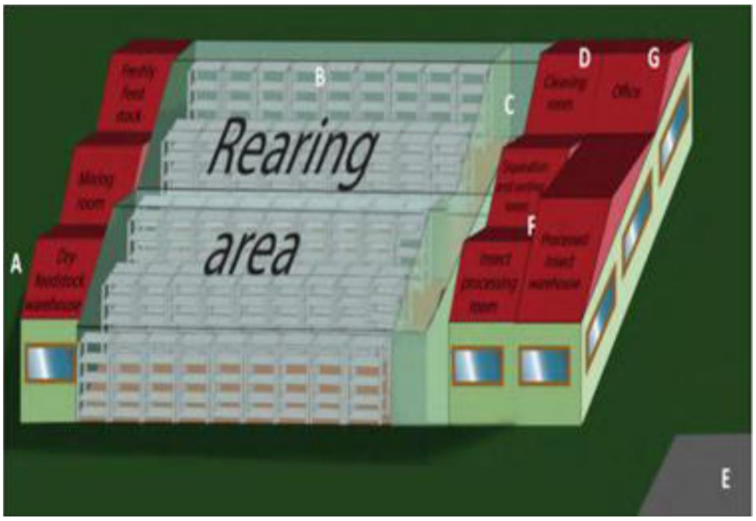
Preparation of new rearing site for *Vespa mandarinia*

Farming

Farming can produce large amounts of insects which can occur at different scales. It can be as simple as a single cage through to a large semi-automated factory.

Insects may not necessarily be the main form of food or income for the farmers, but insect farming provides a potential longer term resilient food supply. The environmental benefits of farming include habitat conservation but the natural environment needs to be retained as a source of renewal and also as a safety net and will still be important for local food supply and livelihoods. One disadvantage of farming is the potential for exotic species introduced for farming to escape, become established and have detrimental impacts on the natural environment.

Designed structure of modern insect farm showing distribution of the operations (Ortiz *et al.* (2016)



A. Feedstock warehouse
B. Rearing area
C. Harvesting room
D. Cleaning room
E. Compost area
F. Insect processing room
G. Control room

A. Feedstock warehouse

The feed or raw material is stacked in this place

B. Rearing area

For an efficient insect production, it is necessary to use the rearing space efficiently. For some insect species which can crawl vertically, jump, or fly, three-dimensional crawling space (such as cardboard dividers, egg crate material, or a more permanent lattice of some material or another) can allow for greater density versus depending only on two-dimensional flat spaces. For those limited to the bottom of a flat surface (most larvae such as mealworms and fly larvae, etc.), it is important to minimize space between trays with insects and feed/substrate while balancing against the need to deliver air and regulate temperature. In some cases, stackable boxes can be used or the boxes can be set on a wagon or a pallet to allow free movement around the rearing area. The climate control system must be capable of maintaining adequate environmental conditions in the rearing area.

C. Harvesting room

When insects are ready to be harvested, they are cleaned and separated from frass in the harvesting room.

D. Cleaning room

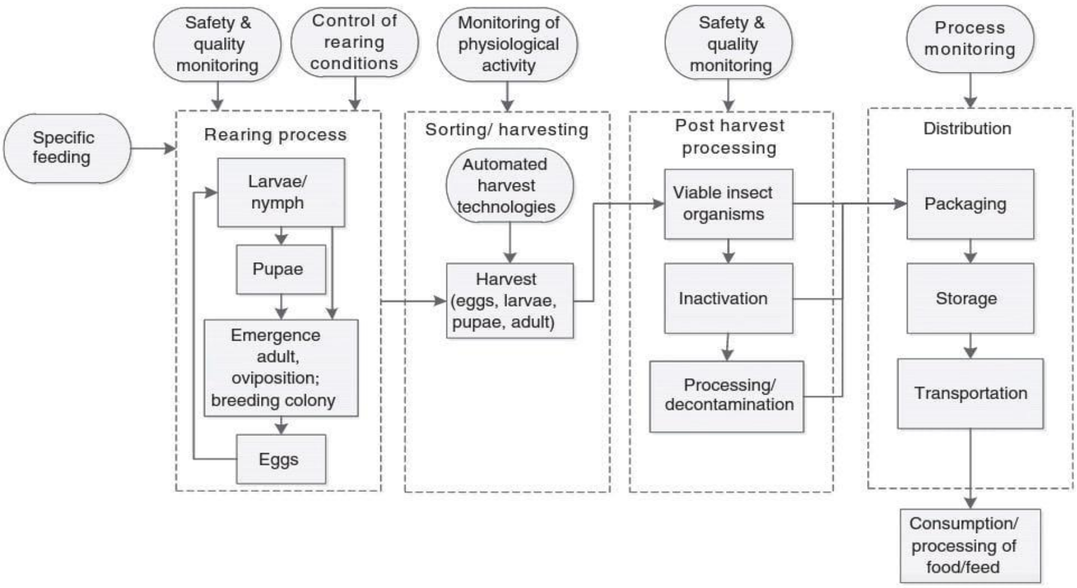
All rearing boxes must be designed for easy handling and made of structurally resistant materials that can be washed multiple times. Edible insects separated by age and size are either sent back to the rearing area or packaged for shipment to the process area. Dead insects and waste are stored and collected weekly by an authorized company for destruction.

E. Compost area

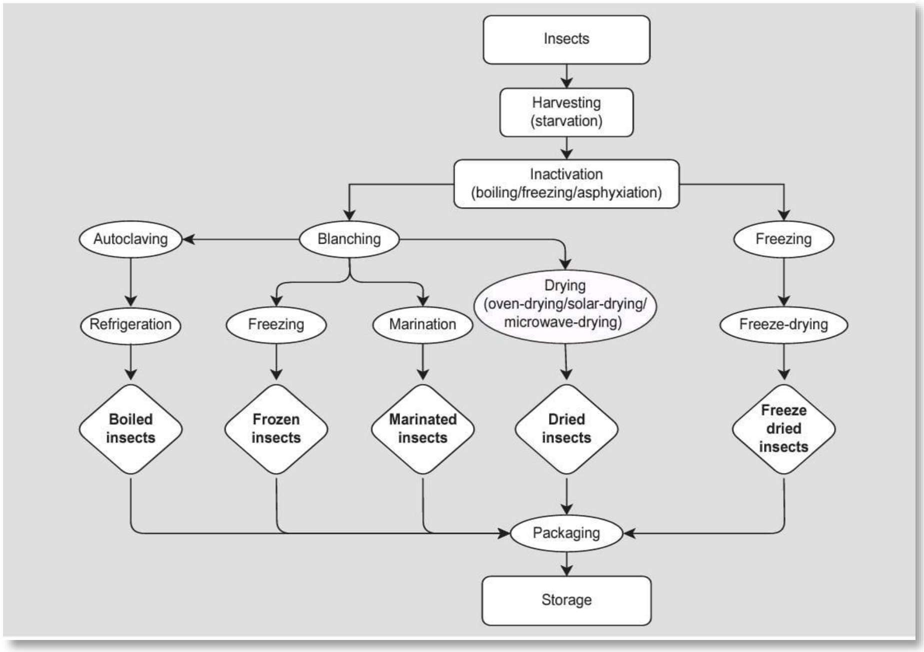
Frass separated from live insects and feed residue can be collected and processed or packaged for other applications (such as fertilizer or feed for other animals) in a separate area from the rearing or cleaning room.

F. Insect processing room

Insect feed processing includes the use of sustainable procedures, for instance, the use of water/energy and economic feasibility (cost, etc.). Food processing technology significantly influences feed functional properties which may lead to reduced digestibility or loss of feed nutritional value, as well as reduced acceptability to the insect due to changes in flavor, aroma, texture, color, or other properties.

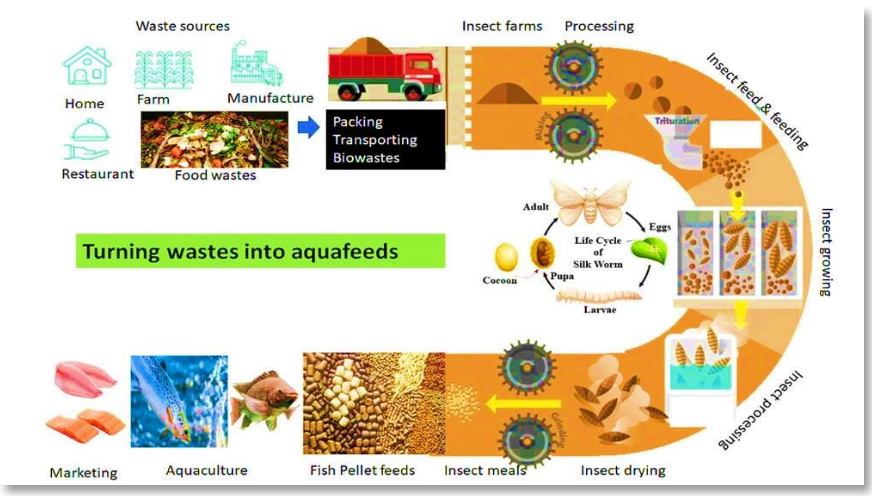


Schematic production process of food and feed derived from edible insects (Rumpold and Schluter, 2013)



Processing pathways for production of whole edible insects Ojha *et al*. (2021)

To produce insect meals, there are several essential steps as described by Alfiko *et al.*, 2021. The first step is to ensure the availability of biomass, which should be continuously available since the nutrient composition of growing substrates has a great influence on critical production factors like total larvae yield, individual larva body weight, and nutrient composition of yielded insect larvae. The second step is decontamination, which is carried out using thermal or radiation processes. Drying the insect pupa or whole body with convection, and contact/radiation is the third step. The fourth step is breaking the insects or pupa into small pieces using grinding. In some insect species (e.g., yellow mealworm), it is essential to have the fourth step to extract fat from insects, which is the defatting process.



Turning wastes into proteins using insects to produce insect meal to replace fish meal concerns (FAO, 2021)

Biological hazards

While pathogenic microbes of insects (entomopathogenic) are considered harmless to humans and animals due to phylogenetic differences, insects can be a vector for various microorganisms that are detrimental to human and animal health, especially under poorly controlled hygienic conditions. The risk of transmitting zoonotic infections to humans through edible insects seems low, but this topic requires greater research to clarify the potential risks for food and feed

Bacteria: Several bacterial species have been associated with edible insects, both farm-reared and wild-caught. These include some bacterial species from the genera Staphylococcus, Streptococcus, Bacillus, Pseudomonas, Micrococcus, Lactobacillus, Erwinia, Clostridium and Acinetobacter as well as members of the family Enterobacteriaceae. Certain members of these genera and family are not only pathogenic and opportunistic bacteria but they can also be responsible for reducing the shelf-life of edible insects. Rearing materials can also determine if there are any potential microbiological risks to consider. Rearing materials can also determine if there are any potential microbiological risks to consider. The presence of endospore-forming bacteria in edible insects is another major food safety concern as the spores, being heat-resistant, may withstand the common processing methods adopted for edible insects, like drying, boiling and deep-frying.

Viruses: So far, risks associated with foodborne viruses, like hepatitis A, hepatitis E and norovirus, from consuming edible insects are low, but care must be taken not to introduce the viruses in insect production units through substrates. Insects can potentially serve as replicative vectors for viruses that infect vertebrates. Additional studies are needed to investigate the possible occurrence and transmission of arthropod-borne arboviruses, which can cause a number of human diseases.

Fungi: Foodborne fungi can be responsible for food spoilage through product quality deterioration and nutritional losses. In addition, some of the fungi are pathogenic to humans and can form mycotoxins that are extremely harmful to humans.

Parasitic hazards: Insect species deemed fit for mass production may be vectors for parasites and this hazard must be given due consideration. However, the parasitic risks associated with edible insects that can affect humans are poorly documented.

Chemical hazards

Mycotoxins: Several mycotoxins such as Beauvericin, enniatin etc have been detected in edible insects, albeit not at levels that give rise to public health concerns

Pesticides: Pesticides used on agricultural produce may accumulate in insects that are raised on treated plant-based side stream materials.

Toxic Metals: Accumulation of toxic metals by edible insects has been found to be associated with a number of factors including the metal type, insect species, growth phase, the substrates used and environmental contamination. For insects to be used as food and feed, maximum levels of certain heavy metals like cadmium, lead, mercury and arsenic need to be evaluated based on insect species.

Trace Metals: It is also important to pay attention to the levels of trace minerals (iron, manganese, magnesium, copper) obtained from consuming certain edible insect species. However, at this point, it still not clears how much of the trace metals are bioavailable upon consumption.

Physical hazards

Dehydrated insects consumed whole can pose physical hazards due to the hard parts of the insects, such as stings, wings, rostrum, and spines on shinbones which can cause physical obstructions. Consumers must be informed of the presence of these insect parts in the food products.

Allergens

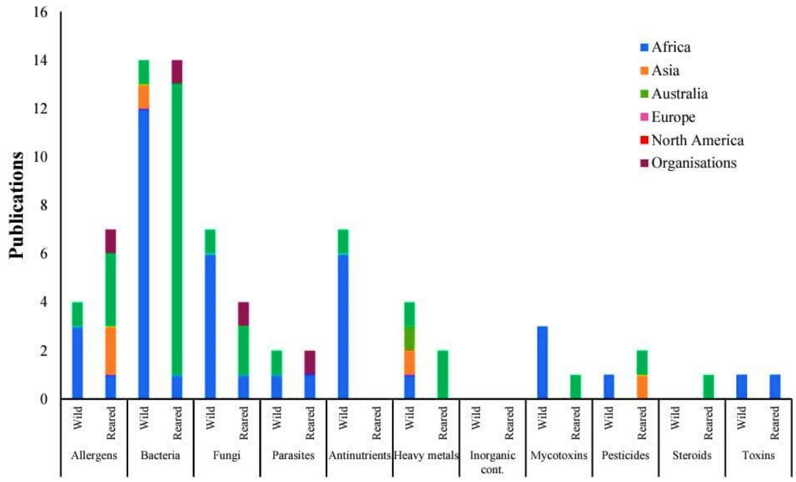
Known panallergens that cause cross-reactive allergies include arginine kinase, tropomyosin, glyceraldehyde-3-phosphate dehydrogenase, hexamerin1B, sericin and haemocyanin. Allergic reactions to insects via inhalation or skin contact have also been documented. Workers on the insect farms may be prone to experiencing adverse reactions at their job sites.

Antimicrobials

It is possible that antimicrobials may be added as a contingency measure to control microbiological issues in industrial rearing facilities which may get accumulated in the substrate.

Soren *et al*. (2021) assessed the nutrient and toxic heavy metals of *Tarbinskiellus portentosus* and *Schizodactylus monstrosus* which were used as food by Bodo tribe in Assam. They reported that *T. portentosus* showed a significantly higher value of 0.008 ppm arsenic, 0.038 ppm lead, and 0.015 ppm cadmium whereas *S. monstrosus* on the other hand showed significantly lower values of 0.002 ppm arsenic, 0.008 ppm lead, and 0.004 ppm cadmium. Although the insects are rich in nutrients and minerals, presence of toxic heavy elements indicate environmental contamination and hence, their consumption should be done with caution or avoided.

Many publications reporting various hazard distribution based on production method are depicted below as reported by Murefu *et al*. (2019).



Strengths

- Traditional usage by ethnical peoples
- Outstanding research and infrastructure in agricultural and biodiversity sectors
- Global market demand for alternative proteins
- Ability of edible insects to withstand global disruptions in the food supply chain

Weaknessess

- Limited knowledge on nutrition, farming, production and safety of native species.
- Neophobia and misguided public perceptions of insects
- Insect food product costs are considered expensive currently due to high labour costs.
- Lack of farming automation limits scalability of industry

Risks

- Allergic reactions and sensitivities to insect products
- Insects might carry biological and chemical contaminants or act as physical hazards affecting consumer health.
- Lack of funding, resources and buy in from researchers, industry and governments.
- Potential for alternative plant based foods preferred over insect derived products.
- Media and community perpetuating insect stereotypes.

Challenges

Food and feed acceptance

- Overcoming food neophobia among the consumers

Regulatory barriers

- Absence of regulatory frameworks to support, production, risk assessments, quality control measures and commercialization

Research gap towards food safety

- Further research is needed to establish safety of insect based products used as both food and feed

Production concerns and good hygiene practices

- Scale, biosecurity issues and implementing good farming and hygiene practices

Financial investments

- Procuring investments can be difficult to unclear regulations about production and commercialization

Call to action

- Identifying cultural, health, environmental and commercial challenges for incorporating edible insects in to our diet
- Take advantage of unique biodiversity, skills and infrastructure to innovate
- Seek out new oppurtunities, collaborations and investment to expand the market
- New research and development to fill the knowledge gap and create new processes, services and products.
- Develop and implement new policies and practices from farming to product labelling
- Reevaluate and adapt to national and international markets.

Role of stakeholders

The communication strategies of stakeholders need to be comprehensive and should target region, culture, locality (rural, urban), economics, environment, nutrition, gastronomy and tradition.

Governmental bodies

Governmental bodies have important roles to play in promoting insects as food and feed.

- awareness and collaboration among relevant ministries, such as agriculture, health and the environment
- the implementation of existing policies and the creation of new policies, such as food and feed regulations
- the creation of incentives aimed at knowledge centres for research, development and graduate and post-graduate training
- the creation of incentives aimed at the private sector for investment and technical development

- the provision of technical assistance in sustainable insect harvesting and insect farming through agricultural extension services.

Industries

- Industrial producers have undertaken research and development on insects in cooperation with knowledge institutions with the objectives of centralizing scattered information including data, literature, economics, methods and practices as a basis for investment options. Industry can further advance insects on the agenda by contributing to investment in infrastructure, research and technology, and can increase awareness by marketing products to the general public.

NGO's

- NGOs play a significant role in increasing awareness of entomophagy, as well as in promoting insect rearing as a diversified livelihood strategy. Environmentally oriented NGOs can help to strengthen guidelines for sustainable harvesting through governmental lobbying and practical experience in local communities.
- NGOs can also raise awareness of this already significant informal activity and promote it as an environmental strategy for food and feed on political agendas in both developed and developing countries.
- Moreover, NGOs can assist in technical training for rural, peri-urban and urban households on market linkages, entrepreneurship, the domestic rearing of insects, and the identification of producers' objectives (such as subsistence, semi-commercial and commercial enterprises).

Gastronomic enterprises

- Making insects tasty and attractive is one of the biggest challenges facing new insectbased food enterprises
- These organizations focus on optimizing colour, texture, taste and flavour to make insects appealing to the Western palate.

Foretaste (Future prospects)

- New research to Identify and develop native species feasible for commercialisation.
- Identify nutritional profiles and their impact on human health
- Conduct clinical trials to test health benefits of consuming insects
- Identify target customers for all demographics
- Test public perceptions and experiences
- Improve farming practices to reduce potential allergies and sensitivities
- Optimize hygiene safety practices for rearing to labelling insects

- Develop assessment tools to compare environmental foot prints and production costs of insects versus other foods
- Consulting with state and central govts to regulate industry
- Encourage industry collaboration.

Conclusion:

- ✓ Insects represent a sustainable source of food for 21st century as they can meet all nutritional demands requiring fewer resources to produce than most meat based proteins derived from livestock.
- ✓ For distribution and consumption of industrially mass-produced insects as food all over the world, education of the public as well as image improvement of edible insects needs to be performed in order to establish and increase consumer acceptance.
- ✓ In order to produce insects on an industrial scale, technological improvement of rearing facilities for automated, cost-effective production processes are to be implemented..
- ✓ As with all foods, it is important to account for the possibility of risks in insects so, it is necessary to establish a hygiene and disinfection protocol that guarantees the food safety of insect derived products.
- ✓ Enhancing research on knowledge gaps, developing appropriate regulatory frameworks and encouraging collaboration among stakeholders will facilitate establishing a multidisciplinary pathway for the sector.

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BIOFERTILIZERS FOR FUTURE FARMING

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Abstract:

In India the availability and affordability of fossil fuel based chemical fertilizers at the farm level have been ensured only through imports and subsidies. Today, biofertilizers have emerged as a highly potent alternative to chemical fertilizers due to their eco-friendly, easy to apply, non-toxic and cost effective nature. Also, they make nutrients that are naturally abundant in soil or atmosphere, usable for plants and act as supplements to agrochemicals. Biofertilizers are essential components in maintaining long term soil fertility and sustainability by fixing atmospheric nitrogen, mobilizing fixed macro and micro nutrients thereby increasing their efficiency and availability. Biofertilizer can not only substitute inorganic fertilizers but also helping the soil health. Biofertilizer along with organic will help in improving nutrient use efficiency, protect nutrient against losses such as leaching, volatilization losses and reduce soil and environmental degradation. Biofertilizers have greater role in increasing crop production. Hence, the use of biofertilizer should be a proper option for sustainable agriculture.

Keywords: Agriculture, Biofertilizers, Farming, Microbes

Introduction:

Global demand for agricultural products is increasing due to the increasing human population. There are already about 7.9 billion people on the planet and this number is expected to rise, with a projected growth of almost 10 billion in the next 50 years (Fig. 1). As the world's population continues to increase so does the demand for food; hence, feeding the current vast population and to meet the challenges of food scarcity caused by the rise in population, various agricultural alternatives such as the use of chemical or synthetic fertilizers, pesticides and insecticides have been used to produce crops with high yield within the shortest time possible and to protect them from insects and pest attack during and after harvest. However the use of these fertilizers and insecticides has raised much public concern about the sustainability, safety, and security of the food supply.

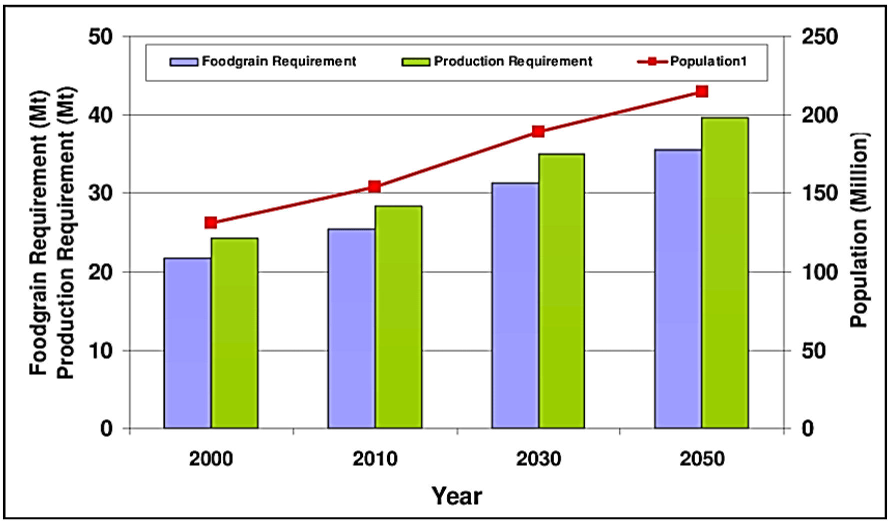

Fig. 1: Population in India from 2000 to 2050

There is a significant amount of pesticide residue present in foodstuffs long after they are taken away from farms for human consumption; hence, the need for alternatives such as biofertilizer in ensuring food safety and security. Biofertilizers can prove a boon to sustain our agricultural production and to meet the demand of increasing population for agricultural-based products while conserving and sustaining the natural resources for future generation. Importance of biofertilizers in enhancing productivity and quality of agricultural products. Moreover, synthetic fertilizers that consist of various nutrients such as nitrogen, phosphorus, potassium and sulphur may become harmful if used beyond the required amount. The harmful effects of these fertilizers include the depletion of soil nutrients resulting from continuous tillage and the use of chemical or synthetic fertilizers for continuous agricultural production. This have made the soil lose its fertility and degradation of cultivable land and ecosystem and the weakening of plant roots, the high rate of disease incidence, soil acidification and eutrophication of ground water and other water bodies. Nutrients such as nitrates leach to groundwater and cause “blue baby syndrome” also called “acquired methemoglobinemia”. The impact of these chemicals will not only affect the present but also future generations. Therefore, there is need to search for eco-friendly approaches such as biofertilizers, which play a major role in sustainable agriculture (Daniel *et al.*, 2022).

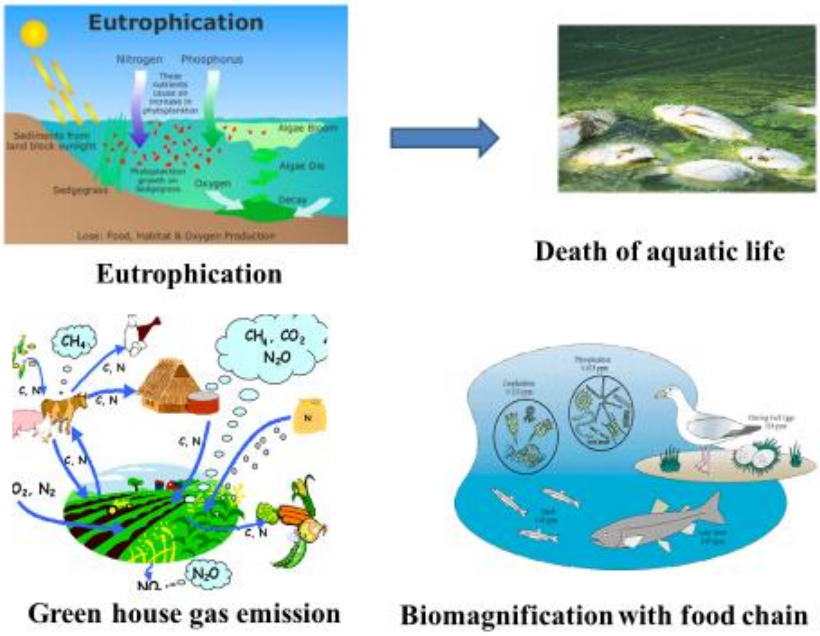

Fig. 2: Harmful effects of using chemical fertilizers

1. Biofertilizer

Biofertilizer can be defined as biological products containing living microorganisms that, when applied to seed, plant surfaces, or soil, promote growth by several mechanisms such as increasing the supply of nutrients, increasing root biomass or root area and increasing nutrient uptake capacity of the plant. Biofertilizers add nutrients through the natural process nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth promoting substances.

2. Types of biofertilizers:

Biofertilizers are divided into groups based on their functions and mechanisms of action. The most commonly used biofertilizers are nitrogen-fixers (N-fixers), potassium solubilizers (K solubilizers), phosphorus solubilizers (P solubilizer), and plant growth-promoting rhizobacteria (Mazid and Khan, 2015).

1. **Nitrogen fixing** (Free living, symbiotic, and associative symbiotic): increase the amount of N2 in the soil by fixing atmospheric nitrogen and making it available to plants.

   Examples: *Rhizobium*, *Azotobacter*, *Anabaena azollae*, *Frankia*, *Rhodopseudomonas*, *Azospirillum spp.*

2. **Phosphorus mobilizing** (Mycorrhiza): Phosphorus is transferred from the soil to the root cortex. These are bio fertilizers with a wide range of applications.

   Examples: Arbuscular mycorrhiza, Acaulospora spp., Gigaspora spp., and Sclerocystis spp.

3. **Potassium solubilizing** (Bacteria): Produce organic acid that degrade silicates and aid in the removal of metals to solubilize potassium ions and make it available to plants.
   Examples: *B. edaphicus, Arthrobacter spp., Bacillus, Mucilaginosus, B. circulanscan.*
4. **Potassium mobilizing** (Bacteria): They transfer potassium from the soils inaccessible forms. Examples: *Bacillus spp*.
5. **Micronutrient** (Zinc solubilizing): Protons, chelated ligands, acidification, and oxidoreductive systems can all be used to dissolve zinc.
   Examples: *Pseudomonas spp., mycorrhiza, and bacillus spp.*
6. **Plant growth promoting** (PGPR): produce hormones that encourage root growth, increase nutrient availability. And boost crop yields.
   Examples: *Agrobacterium, pseudomonas fluorescens, arthrobacter, bacillus, rhizobium, xanthomonas.*

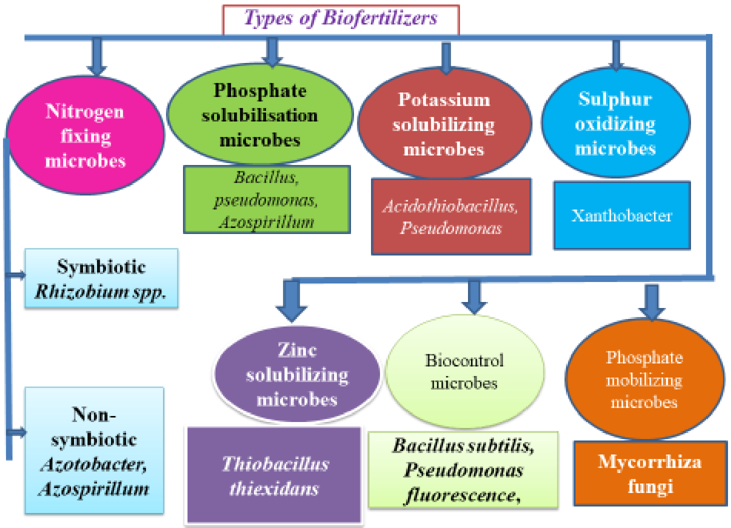

Fig. 3: Types of Biofertilizers

Rhizobacteria: They form root nodules in leguminous plants and fix the atmospheric nitrogen into an organic form. Rhizobium also has no negative effect on soil quality and improves the quality, nutrient content, and growth of the plant. It fixes atmospheric N in symbiotic association with legumes with 50-100 kg N ha^{-1}. And 20g of Rhizobium culture is required to treat 1 kg seed. And it supplies 15-20 kg N ha^{-1} and increases yields of up to 10- 35 %.

Azospirillum: Unlike Azotobacter, these can be used in wetland areas. They are found inside the roots of the plant (non-free-living) where they fix the atmospheric nitrogen. Fix N in the range of 20-40 kg ha^{-1} in the rhizosphere in non-leguminous plant. It involves the Production of growth promoting substances. And Increases yields of up to 5 - 30 %.

Azotobacter: These are free-living nitrogen fixers found in all types of upland crops. These not only fix nitrogen but also provide certain antibiotics and growth substances to the plant. And fix atmospheric nitrogen non-symbiotically nearly 20-25 kg N ha^{-1}. Azotobacter are very fast growing and increases yield by 10-20 %.

Azolla: azolla is free floating water fern used as biofertilizer for wetland rice. It fixes atmospheric nitrogen in association with nitrogen fixing blue green algae *Anabaena azollae*. And it contributes 30-100 kg N ha^{-1} per rice crop. *Azolla pinnata* is most tolerant to high temperature (30-35ºC).

Blue-green algae: These are free-living nitrogen-fixing Cyanobacteria that are present only in wet and marshy lands. However, they do not survive in acidic soil. They have heterocyst *i.e.* capable of fixing atmospheric nitrogen. The benefit due to algalization could be the extent of 20-30 kg ha^{-1} nitrogen fixes. And it improves soil aeration, water holding capacity and add to biomass when decomposed in life cycle.

Phosphate solubilizing bacteria: Phosphate is Low levels of mobility, solubility and its tendency to become fixed in soil by PSB it converts insoluble phosphates into soluble forms in soil. Secrete organic acids *i.e.* formic, acetic, propionic, lactic and succinic. It improves the soil aggregation.

Arbuscular Mycorrhizal fungi: It is a symbiotic association between the fungi and the roots of a plant. The mycorrhizal fungi play an important role in binding the soil together and improves the activity of the microbes. The fungi draw water and nutrients from the soil thereby increasing the plant productivity. It also helps the plant to survive under various environmental stresses. They transport P and other nutrients from the deeper layers of soil and deposit in plant roots. And helps the Higher nutrient uptake especially P and micronutrients. It saves nearly 25 to 50 % phosphatic fertilizers in groundnut. Increases yield by 30 - 40 %.

Plant Growth Promoting Rhizobacteria (PGPRs):

It acts as both Biofertilizer and Biopesticides and Promote growth by:

a) Improved nutrient availability (**Biofertilizers**)

b) Suppression of plant disease (**Bioprotectants**)

c) Phytohormones production (**Biostimulants**)

Fig. 4: Different Biofertilizer products

Scope and future perspectives of biofertilizers

1. The use of biofertilizers can play an important role in sustaining the agriculture systems. In India, where fertilizer is annually hundred billion rupees business, even 10 % contribution by biofertilizer can save 10 billion rupees.
2. Biofertilizers offer huge potential for widespread use offering both economic and environmental advantage to farmers as well as commercial viability to production units.
3. Various research groups or organization are engaged in research and development on biofertilizers and have made their efforts to increase the application of biofertilizers in India agriculture.

Assuring quality of products, concept of food security and concept of safe food with extensive field-based testing, capacity building of human resource and stakeholders on standard production processes, storage and application will help a wider adoption and popularization of the biofertilizers technologies in India.

The state wise consumption of bio fertilizer in India was highest in Tamil Nadu and Gujarat

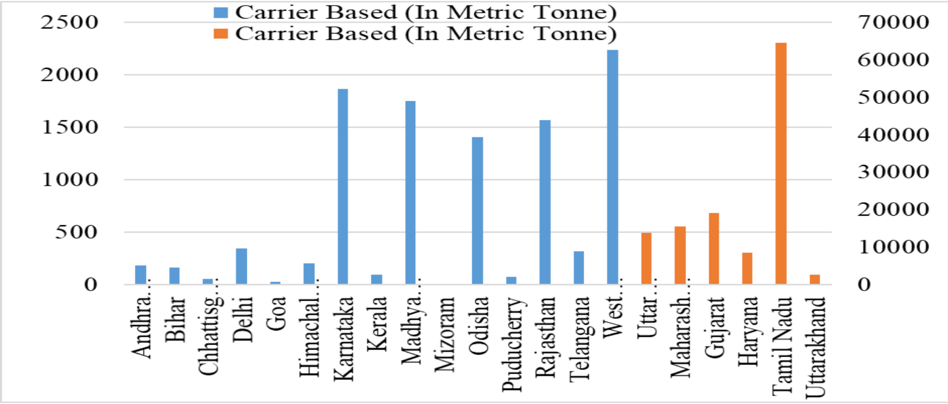

Fig. 5: State-wise consumption of bio fertilizers in India 2020-21

List of biofertilizer units in India and Abroad:

1. National Biofertilizer Development Centre, now it is National Centre of Organic Farming, Gajiabaad, Uttar Pradesh, india.
2. Biofertilizer Production Unit Government of Tamil Nadu kukumiamalal, Pudukkottai, Tamil Nadu.
3. Agriculture Bacteriology Section College of Agriculture, Pune, India.
4. Bio-Care-Techonology. Pty.Ltd. New South Wales, Australia.
5. Agrproyectos Rivadavia Yobipo, Gelabert, Argentina.

Role of biofertilizers (Kant *et al.*, 2017)

- They supplement chemical fertilizers for meeting the integrated nutrient demand of the crop
- Application of bio fertilizers results in increased mineral and water uptake, root development, vegetative growth and nitrogen fixation.
- They liberate growth promoting substances and vitamins and help to maintain soil fertility
- They improve physical properties of soil, soil tilth and soil health in general.
- They improve soil fertility and soil productivity.

How biofertilizer is more beneficial than chemical fertilizer

- Eco-friendly and renewable source of plant nutrients
- Improves soil fertility
- Enhance nutrient uptake and water uptake in deficient soil
- Improves soil properties
- They are cost effective

- They act as a biocontrol to pathogens in both soil and plant and work as a natural pesticide.

Methods of biofertilizer application

1. **Seed inoculation (200g/10 kg of seed):** Biofertilizer is mixed with 10 % jaggery and slurry is prepared and poured on the seeds to form a thin coating on the seeds.
2. **Soil application (5kg/100 kg FYM/ha):** 5 kg of biofertilizers (PSB, Azospirillum, etc.) are mixed with 50- 100 kg of well decomposed cattle manure for an area of 1 ha. The mixture of biofertilizer and cattle manure sprinkled with water is kept for 24 hours and then broadcasted into soil at the time of sowing.
3. **Root and seedling treatment (1 kg /10 litre water /ha):** Dip the root portion of the seedlings in this suspension for 15-30 minutes and transplant immediately. Generally the ratio of inoculant and water is 1: 10.
4. **Setts or tuber treatment (1 kg/40-50 litre of water/ha):** Prepare culture suspension by mixing 1 kg of biofertilizers in 40-50 litres of water. The cut pieces of planting material required for sowing one ha are kept immersed in the suspension for 30 minutes. Bring out the cut pieces and dry them in shade for some time before planting. After planting, the field is irrigated within 24 hours.
5. **Standing crop treatment:** Apply a mixture of biofertilizer and FYM by incorporating it into the soil followed by irrigation. Foliar application is also applied in standing crops.

To promote the application of biofertilizers among farmers to obtain higher agricultural sustainability which can be achieved through the following:

- Awareness should be created among farmers regarding benefits of biofertilizers in providing good soil health, sustaining productivity of natural resources, and attaining high productivity and higher cost–benefit ratio.
- Main emphasis should be on the quality control during production process of biofertilizers to keep their potency intact for long time.
- Subsidies on biofertilizers should be provided to farmers to accelerate the use of biofertilizers among farmers.
- Research on biofertilizers with multi-strain and multi-microorganism consortia should be carried out on a large scale for the improvement in crop productivity. Compared to single-strain biofertilizer, multi-strain and multi-microorganism consortia can achieve higher productivity even under hostile growing situations.
- Biofertilizers should made easily available for farmers and large-scale production of biofertilizer should be initiated by providing training and capacity building to industrial

people, farmers, and other growers regarding production, quality control, and use of biofertilizers.

Conclusion:

- Biofertilizers are essential components in maintaining long term soil fertility and sustainability by fixing atmospheric nitrogen, mobilizing fixed macro and micro nutrients thereby increasing their efficiency and availability.
- Boifertilizer along with organic will help in improving nutrient use efficiency, protect nutrient against losses such as leaching, volatilization losses and reduce soil and environmental degradation.
- It have greater role in increasing crop production. Hence the use of biofertilizer should be a proper option for sustainable agriculture.

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EVOLUTION OF AGRICULTURE AND ANIMAL DOMESTICATION

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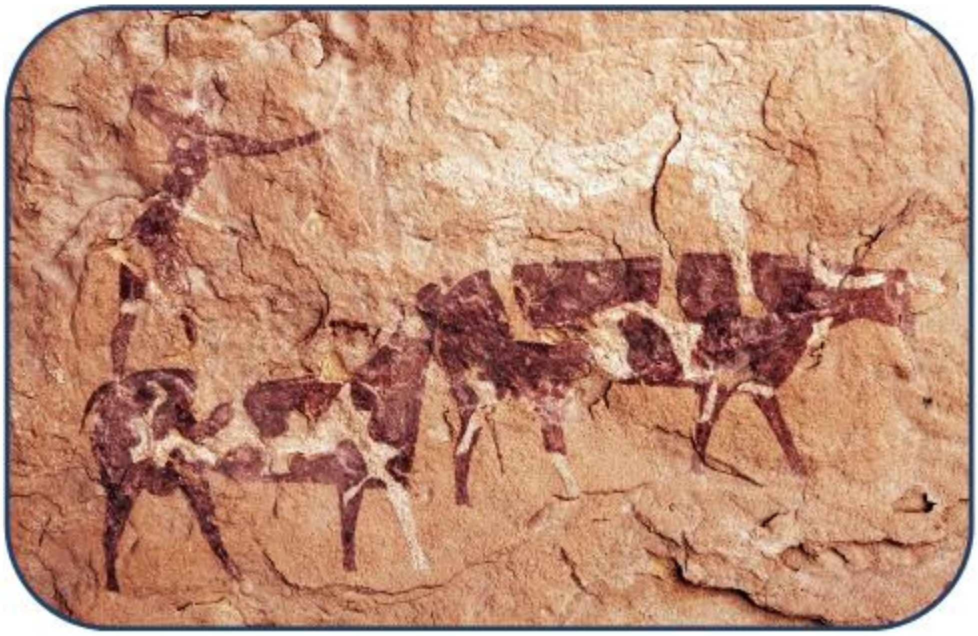
Introduction:

"Domestication" is considered as a developmental and continuous activity where animals (wild) are selected by means of human interventions. Big phenotypic, physiological and behavioral changes are notices after their selection. Extreme influence on human community have been noticed at same instance in different geographical regions of earth, multiple evidences are there which supports this statement. Domestication process is sometimes believed as a cumbersome process which includes several stages, this process changes the domesticated relatives, to their wild ones.

The process of Domestication is well renowned for its low-speed course, extreme economical and technical changes, and, hunting and food items. Big demographic changes, agricultural practices, valuable's animal husbandry, profound alterations in social life are some of the important factors which decides the process of domestication of an animal. In the Neolithic time, the cultural development from hunting of animal to practicing animal farming in old society are connected to the basics of domestication. The origin of social life, community and domesticated species evolution are important factors to be considered in order to comprehend, the process of domestication and its stages.



Definition

Domestication is defined as:

i. makes a healthy commensalism relationship between domesticator and domesticate,
ii. an evolutionary process,
iii. result of mutual ecological influence,
iv. includes an environment construction, where one species in monitored and controlled by the other one, and
v. the domesticates helps the domesticator to gather essential resources and services.

The terms “tame” and “domesticated” animal are used synonymously multiple times, yet they hold a very grate difference. The term "tame" refers to solely one individual animal within a species /or variety. Whereas, the term "domesticated" refers to an entire variety/ or species. The animals have truly never been domesticated which were tamed in thousand number by the humans. Still there is a lot to be discussed, whether the animals’ species are just tamed or have truly been domesticated. A big questionable statement among the researcher is, does the elephants are domestic animals? Also, why the cat hasn’t been domesticated.

Origins of domestication

Since past few decades, researcher has diverted their keen interest in comprehension of domestications basic concepts from recovering animals’ fossils and civilizational centers on earth. Scientists have come up with the findings that the starting of plant cultivation and animal farming and their domestication led to the village life settlement. These studies and findings give rise to various theories and thought about the reasons of what led the human life settlement and why this process kept on continuation in different geographical locations. These theories by different researchers have been discussed below:

1. Climatic Stress Hypothesis – The Oasis Theory

By: Gordon Childe (1925)

This theory emphasis on that the agricultural activity doesn’t start world wide scale at the same time. The basic idea behind this theory was of socio-economic activities. These activities were seen in limited area blocks of few hundred miles in distance. Fierce climatic changes were the ultimate reason for beginning of farming activities in parts of fertile regions. Starvation levels were on high due to the climatic changes like severe draught. Which ultimately led to the concentration of animals, humans and plant in the oasis belt, which were green patches intervened by large desert tracts. The symbiotic relationship among animals, plants and human are being encouraged by the contrast effects of altering warm and dry environment.

2. Nuclear-Zone Hypothesis

By: Robert Braidwood (1950)

As per this theory, increase in food production was on gradual basis. The so called 'Nuclear zones' or 'Natural habitats' are the prime mist regions where the farming had begun. These areas include plentiful plants and animal varieties. According to Braidwood, the process of change had to be seen in the context of changing human culture which he stated in terms of ever-increasing cultural differentiation and specialization of human communities. The reason he gave to support his statement that these changes had never seen before was "the society and the human culture were not prepared to accept these changes". However, this theory failed to explain why such development occurred.

3. Demographic Hypothesis

By: Lewis Binford (1968)

Binford emphasized that, increased population of hunters and gatherers eventually caused extensive territorial area and intervention of marginal places such that the possibilities of further extension got vanished. Hunting and gathering was stopped due to high increase in human population who exploited the resources and a state of saturation was developed. The resource deficient areas compelled the human population for migration to areas which supported food resources and more potential for human development. And this ultimately led them to undertook agricultural practices.

4. Ecological Hypothesis

By: Carl Sauer (1952)

The fundamental of this theory is based on the following points:

1. Food scarcity was not the main reason for the beginning of agriculture practices. As starvation doesn't motivate people to experiment with enhancing food production from plants.
2. The "hearths of domestication" were the places which led to the diversification of animals, humans and plant crops by diversity in both terrain and climate.
3. The riverine regions are most prone to floods and humidity, so possibly domestication and farming didn't begin in river valleys.
4. The initial farmers who practiced agriculture had achieved skills the led them to domestication.
5. Ploughing, sowing and irrigation requires constant monitoring and observation, this makes agriculture more sedentary. Field plantation left after seed sowing till harvesting would invite predators and wild animals, eventually lose to farming crops (Wright, 1990).

As per this hypothesis, fishing introduced humans to agriculture as it permits more sedentism and provided opportunity to people for their lengthy stay at one place. Carl theory supports that, the fishermen living on river banks in a moderate climate were more progressive and proactive. Free time from fishing motivated humans to exploit new opportunities in the nearby regions for new resources, animals and plant species.

5. Social Hypothesis

By: Barbara Bender (1975)

The social models draw upon social compulsions of exchange and the need to conduct feasts and ceremonies by individuals and groups in order to garner social ties.

There was the development of new relationship of "trade and exchange" in food commodity (both in perishable and non-perishable goods) among the members of hunters and gatherer society. For increasing sedentary lifestyle among earlier agriculture practitioner and society, the need of production was the main driving force which motivated people to exchange. Greater social alliance, sharing, harmony and cooperations were results of new arrangements which further resulted in reduction of starvation risk among society members. As per Barbara, need of exchange and distribution were the important factors for social relations in early days.

Very recently, Brian Hayden (1995) in his research study argued that the agricultural practices including animal domestication created an essential role in augmentation of leadership qualities of humans who competed with people of different tribes in order to organize great feasts for members of his group or tribe. The main reason for such feast was to boost their social status and prestige, which also decreases the starvation risk among people. This hypothesis holds an essential meaning but simultaneously finds difficulty to validate, document and test.

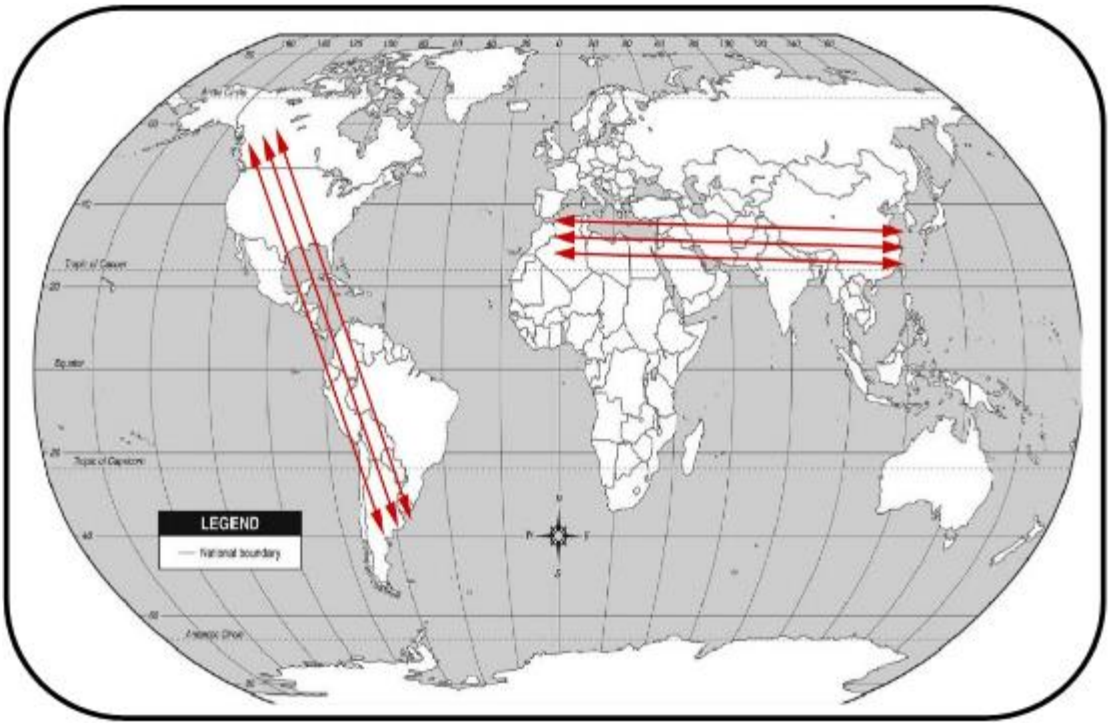
6. Ecological-Evolutionary Theory

By: Jared Diamond (1997)

As per Diamonds theory, the Europe and Asian regions shares a rich environment, which shows kindness to early domestication and also hasten the layout of agricultural activity and crops from these centers to the rest of mankind. This theory claims that cascade cycle is present between intensified agricultural practices for food production, human population and society matrix.

Firstly, In earlier period agricultural practices (Crop farming and animal domestication) aided for sedentary human life-style, which leads to creation of art and craft.

Secondly, very complex division of man power and social stratifications were supported as a result of more intense agricultural practices which were organized to produces surplus food.



Reasons which support Ecological-Evolutionary theory:

1. Long hot days and mild wet winds of tropical climate.
2. Multiple wild varieties and species of agricultural crops and animals have high productivity which grows in large wild strands.
3. These tropical regions contains multiple plant species which were perfect to be domesticated, also this becomes the reason for big herbivores domestication.

Diamond gave reason, that Europe and Asian continent holds the similar climatic differences, day lengths, and often seasons (Same latitudes). Thus, agricultural practices and animals' domestication in one particular area were adapted because they share some of the common factors like seasons due to latitude similarity and day lengths.

Conclusion:

Societal goals have gone beyond food production from animals. Livestock farming is influenced by societal values and consequently can change over time. Social and cultural values are highly desirable characteristic that immensely influences the animal rearing. Therefore, studies are advocated to ascertain socio-culture values of domestic animals (particularly farm animals) reared under different production systems.

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FERTILIZER USE, SOIL HEALTH AND QUALITY OF FORAGE CROPS IN INDIAN SOILS

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Abstract:

In the era of intensive agriculture, scope for diversification of area under forage cultivation is practically impossible because of eager need to meet the demands for the food based crops. But in order to maintain the pace and need, the production of fodder crops have to be increased per unit area to meet the demands targets. Availability of good quality fodder is pre-requisite for sustainable livestock production. Availability of quality fodder had been a hurdle since ages in our country. Intensive agriculture approach has already shown its adverse effects on reduced crop quality, degrading soil properties like soil structure, lowered soil organic matter and ultimately leads to environmental pollution. Continuous research in the field of integration of management approaches had shown a way to reduce the gaps in between forage production and feed supply. Integrated nutrient management (INM) approach has shown its potential in improving crop quality and also maintaining soil health as the approach is focused on combined application of synthetic fertilizers with organic manures. Organic manures are found to have a good impact on improving the soil organic carbon content and also enriching the soil physical and biological properties by enhancing the soil nitrogen content. In numerous studies, application of chemical fertilizers amended with organic manures has proved to be significant practice rather than applied solely. Correction of macro and micro nutrients deficiencies have been found to be positively influenced by INM. Keeping in view the positive response of INM on soil properties and quality parameters of forage crops, the present review study has been done on different aspects of nutrient management practices on forage crops for upliftment of country's farmer's status and establishing equilibrium between demand and supply.

Keywords: Integrated Nutrient management (INM), forage crops, sustainability, deficiency corrections, soil health

Introduction:

Agriculture is the major mainstay of the Indian economy and contributes nearly 14.1 per cent of GDP and about 65-70 per cent of the population is dependent on agriculture for their livelihood (Anonymous, 2020). Livestock production is the backbone of Indian agriculture contributing 24.72 per cent to agricultural GDP, 4 per cent to national GDP and ultimate livelihood for 70 per cent population in rural areas (Anonymous, 2019; Shubham *et al.,* 2022). Adoption of suitable/ improved cultivars and restoring soil health though moderate fertilization is the only way to raise the production scales and to improves nutrient use efficiencies (NUE) (Shubham *et al.,* 2023). Dairy farming supported by intensive forage production system is regarded as a quite profitable alternative to arable cropping system. One of the main reasons for the low productivity is malnutrition or under-nutrition beside the lower genetic potential of the animals. Present population is projected to rise 9.6 billion by 2050, however, the present agricultural production levels would need to increase by 70 per cent in order to feed such outnumbered population (Shubham *et al.,* 2022). The adequate supply of nutritive fodder and feed is a crucial factor impacting the animal's productivity and performance. The feed and fodder availability are facing a shortfall of concentrate (63%), green fodder (62%) and dry fodder (22%) and it may further worsen if necessary, steps would not taken (Karki *et al.*, 2013). By 2050, it is projected that the demand of the dry and green forages will reach 631.05 and 1012.70 million tonnes, respectively. Therefore, urging a need to raise the forage production of the livestock in the country.

The major annual forage crops grown in the country are sorghum, maize, pearl millet and cowpea which are mainly grown in *kharif* season and barley, oats, lucerne and berseem in *rabi* season. Forages being very exhaustive, requires high quantity of nutrients particularly nitrogen. Moreover, intensive forage crop cultivation requires the use of chemical fertilizers, but fertilizers are not only in short supply but also expensive. Therefore, the current trend is to explore the possibility of supplementing chemical fertilizer with the organic ones, especially with organic manure and biofertilizer of microbial origin and adopt integrated nutrient management strategies to improve soil health and crop productivity (Jat *et al.,* 2013).

Use of high analysis fertilizers in an imbalance manner had developed many problems like lesser soil organic matter, increased soil salinity/sodicity, soil pollutants and hazards of pests and diseases (Chakraborti and Singh, 2004; Shubham and Dixit, 2021). To meet out the fodder demand, higher doses of inorganic fertilizers have been provided which are un-economical for fodder production and also indiscriminate and continuous use of high amount of chemical fertilizers had deleterious effect leading to decline in productivity due to limitation of one or more micronutrients in soil surface. Integrated nutrient management is one approach which manages the soil fertility, sustain the agricultural productivity and improve the farmer's profitability through the judicious and efficient use of different nutrient sources. Integrated nutrient management (INM) is the combined use of mineral fertilizers with organic resources such as cattle manures, crop residues, urban/rural wastes, sewage and sludge, different composts, green manures and biofertilizers (Antil, 2012). It is a flexible approach to minimise the use of chemical fertilizers but maximise their use efficiency and farmers' profit. It is essential to sustain crop production by preserving the soil health and biodiversity. The advantage of combining organic and inorganic sources of nutrients in integrated nutrient management has been proved superior to the use of each component separately (Palaniappan and Annadurai, 2007). In general integrated nutrient management is more popular in other countries but it is not so popular in Indian condition due to lack of awareness and negligence in fodder crops. It has tremendous effect in increasing the green forage, dry matter and crude protein yield. In farm land situation where solely, family income is dependent on livestock the integrated nutrient management of forage crops play vital roles for the health of livestock leads to produced higher milk as well as higher income to the farm family. Integrated nutrient management (INM) is not a new concept. It is an age-old practice when almost all the nutrient needs were met through organic sources to supply secondary and micronutrients besides primary nutrients. Overall, this review focuses on integrated nutrient management strategies for maintaining soil health and increasing forage crops productivity and quality.

Effects of INM on soil properties of forage cropping system

Integrated use of organic and inorganic nutrients has shown its superiority by improving in soil physical, chemical and biological properties. Build up of secondary and micronutrients, counteracting deleterious effect of soil acidity, salinity and alkalinity and sustenance of soil health are the key beneficial effects associated with FYM application. Nitrogen is generally taken up by the plant in the form of nitrate (NO_3^-) form under aerobic and as ammonical (NH_4^+) ions under anaerobic condition of plant growth. The nitrogen use efficiency of applied nitrogenous fertilizers have been found to be improved in the presence of FYM in many of the studies conducted by different researchers throughout the country. Substitution of 50 per cent mineral fertilizer-N by FYM under tropical conditions in various cropping system has been found to sustain the soil heath. Application of 50 % N each through urea and FYM obtained significant improvement in soil fertility in terms of available NPK content which was comparatively higher than rest of the treatments (Kumar *et al.*, 2007). Proportions of microbial biomass carbon, microbial biomass nitrogen and organic carbon in soils are very important parameters for assessing soil fertility and productivity.

Many workers reported that integrated nutrient management practices significantly improved macro as well as micronutrient status of the soils. Balanced application of NPK fertilizers with FYM or agricultural wastes improved the soil fertility status in addition to increase in maize yield (Kemal and Abera, 2015). Judicious use of FYM with chemical fertilizers found to improve the soil physical, chemical and biological properties and also improved the sorghum productivity (Sharma *et al.*,2009). The significant improvement in soil organic carbon and available N, P and K status to the extent of 17.8, 6.0, 13.9 and 7.98 per cent, respectively over no sheep manure application which could be attributed to addition of organic matter and increased activity of micro-organisms leading to higher mineralization of applied and inherent plant nutrients in soil (Sharma, 2009). Application of 100 per cent RDN through FYM recorded significantly highest value of soil organic carbon as compared to all other treatments of integrated nitrogen management with highest values of residual nitrogen, phosphorous and potassium. The residual status of nutrients is thus, a function of nutrients supplied and their removal (Singh *et al.*, 2013). Application of FYM also increases cation exchange capacity (CEC) and microbial activity in soil besides supplying macro and micro plant nutrients. It helps in minimizing leaching losses, improving buffering capacity and influencing the redox conditions in the soil. Hence, proper blending of chemical fertilisers with organic manures which are locally available not only improves soil health but also helps to maximize the sustainable production.

The study conducted by Kumar *et al.* (2016) at Hisar, Haryana observed that 100 per cent N through FYM, 100 per cent RDF through inorganic fertilizer and 75 per cent RDF+25 per cent N through FYM+ Azotobacter resulted in build up of the residual status of nitrogen, phosphorus and potassium after the crop harvest than before the sowing. The extent of decrease was less when nutrient supply was made practically through inorganic sources in combination with organic sources as compared to chemical fertilizers alone. Balanced application of NPK fertilizers integrated with farm yard manure (FYM) or agricultural wastes were found to enhance the soil fertility status in addition to increase in maize yield (Kemal and Abera, 2015).

Soil fertility status after post-harvest of cenchrus: cowpea in alternate paired rows showed that physical and chemical properties of the soil (Bulk density, soil organic carbon, available N and P) had improved remarkably with application of 40 kg N/ha + 60 kg P_2O_5/ha + bacterial inoculation (Rhizobium, Azotobacter and PSB) as it is compared with other treatments combinations (control, bacterial inoculation, 40 kg N/ha, 60 kg P_2O_5 and 40 kg N + 60 kg P_2O_5) in sandy loam soils of Avikanagr, Rajasthan (Meena *et al.*,2018). Similarly, application of 80 kg N/ha and 40 kg P/ha (100 % RDF) along with Azotobacter + PSB resulted in increased organic carbon and available N and P followed by 75 % RDF + *Azotobacter* + PSB in loamy sand soils of Gujarat (Patel *et al.*,2018). The microbial population might have increased in this treatment, resulted in soil aggregation and decomposition and increased organic carbon content in soil. The organic acids released during microbial decomposition of organic matter helped in the solubility of native phosphates, as a result of which the availability of P content increased.

The application of 50 per cent (40 kg N/ha) N through urea and 50 per cent N through FYM obtained significant improvement in soil fertility after the harvest of pearl millet crop in terms of available N (174 kg/ha), phosphorus (48 kg/ha) and potash (204.8 kg/ha) which were comparatively higher than rest of the treatments in loamy sand soils of Gujarat (Ram *et al.*, 2015). Application of FYM also increases cation exchange capacity (CEC) and microbial activity in soil besides supplying macro and micro plant nutrients. It helps in minimizing leaching losses, improving buffering capacity and influencing the redox conditions in the soil (Gaur *et al.,* 1971). In the era of increasing population and industrialization, rapid expansion of industries created conditions for modernizing agriculture. Therefore, precision based farming is the key to maintain both the yields level and soil health (Shubham *et al.,* 2020). In another research, Singh *et al.* (2013) studied the effect of integrated nutrient management on the soil fertility status under rain fed conditions in pearl millet crop and found that application of 100 per cent recommended dose of nitrogen (RDN) through FYM recorded highest value of soil organic carbon (0.30%), highest residual nitrogen (146.1 kg/ha), phosphorus (18.9 kg/ha) and potassium (237.8 kg/ha) followed by those receiving 80per cent RDN through vermicompost + 20 per cent through urea. It is quite established that only a part of FYM is mineralized in one season and the rest has carry over effect. The residual status of nutrient is thus, a function of nutrients supplied and their loss/removal. Wailare and Kesarwani (2017) studied the effect of INM on physico-chemical properties of soil and reported that application of 5 t/ha poultry manure and 100 per cent recommended dose of fertilizers (RDF) (120:60:40:: N:P:K) significantly improved the soil organic carbon (1.5 %) and available N (565.4 kg/ha), whereas, soil available phosphorous (19.4 kg/ha) was recorded maximum under 5 t/ha poultry manure + 100 per cent RDF. Rainy period brought higher levels of ammonical and nitrate content accumulation in the soil (Shubham *et al.*, 2021).

Pathan and Kamble (2014) reported that application of recommended dose of fertilizer (20:80:40 kg NPK ha^{-1}), elemental sulphur (30 kg ha^{-1}), sodium molybdenum (1 kg ha^{-1}) and borax (4 kg ha^{-1}) along with FYM (10 t ha^{-1}) to perennial lucerne crop recorded significantly higher values organic carbon (0.45 %) and soil available nutrients *viz.* nitrogen (290.97 kg ha^{-1}), phosphorous (14.42 kg ha^{-1}), potassium (384.23 kg ha^{-1}), sulphur (12.20 μgg-1), molybdenum(0.044 μgg^{-1}) and boron (0.32 mg kg^{-1}) over rest of all the treatments in clayey soils of Rahuri, Maharashtra. The increase in organic carbon content was partly due to the direct addition of organic manure (FYM) and partly through better root growth and also due to better activity of microorganisms. Also, the addition of FYM along with S, Mo and B was found beneficial in improving the status of soil micronutrients. Incorporation of such materials produces the organic acids, organic constituents and ultimately fermentation of humus, which in turn act as chelating agent for micronutrients. Therefore, addition of FYM increased the micronutrient status of soil.

Effect of integrated nutrient management on forage yield

Nutrients from different sources have played a significant role in increasing forage productivity. However, their use in forage crops is very limited due to preferential need for food and cash crops on one hand and on the other, nutrients removal from the soil pool by forage crops specially multi cuts and perennial ones is much higher. Such high removal of nutrient, if not replenished, would widen the gap between addition and removal. A study by Puri and Tiwana (2008) at Ludhiana reported that maize fertilized with 25 t FYM/ha and 100 kg N/ha produced palatable and nutritious fodder in large quantities. Similarly, Duhan (2013) reported that the substitution of 100 per cent recommended dose of nitrogen through FYM increased the fodder yield of sorghum from 41.11 to 56.97 q/ha over absolute control treatment. Choudhary and Gautam (2007) at New Delhi reported that application of FYM @ 10 t/ ha to pearl millet enhanced total green forage and dry matter yield. Application of 50 per cent recommended NPK (40:20:0 kg/ha) fertilizer + vermicompost + FYM each at 5 t/ha recorded significantly higher yield of oats. Application of 50 per cent recommended dose of NPK, vermicompost 5 t/ha and FYM 5 t/ha may be adopted for getting higher, sustainable and quality fodder from single cut oat under irrigated conditions at Jhansi (Kumar and Shivadhar 2006). Pal *et al.*,(2015) reported that application of 10 t/ha FYM along with sulphur (30 kg/ha), boron (4 kg/ha) and molybdenum (1 kg/ha) had higher green and dry forage yield of berseem than application of both treatments either 100 per cent RDF (inorganic source) or RDF with FYM @ 5 t/ha +S+Mo+B. Application of 75 kg N/ha through chemical fertilizer+25 kg N/ha through FYM or castor cake along with the combined inoculation with *Azotobacter chroococcum* (ABA-1) + *Azospirillum lipoferum* (ASA-1) recorded significantly higher green forage yield of forage sorghum in sandy loam soils under middle Gujarat agro-climatic conditions (Yadav *et al.*,2010). Similarly, application of 150 kg N/ha along with 40 kg P/ha and dual inoculation of seed with *Azotobacter chroococcum* (N fixer) + *Pseudomonas striata* (phosphate solubilizer) in multi-cut fodder oat improved the vegetative growth (Jayanthi *et al.*,2002). Application of 20 kg N + 60 kg P plus mixture of *Rhizobium trifolii* and phosphate solubilizing bacteria (PSB) recorded highest green fodder (65.45 t/ha) of berseem (Meena and Mann, 2018). Basanthi *et al.* (2012) reported that application of farm yard manure with *Rhizobium*, phosphate solubilizing bacteria and *Azospirillium* resulted in maximum fresh forage yield (1.67 t/ha). Higher green herbage of oat were obtained with integration of either vermicompost @ 5 t/ha or FYM @ 10 t/ha and *Azotobacter* with 75 per cent of recom mended dose of fertilizer (100% RDF-80 kg N/ha, 40 kg P/ha) resulted in saving of 25 per cent chemical fertilizers (Godara *et al.,*2012). Devi *et al.* (2014) at Hisar found that Azotobacter inoculation produced significantly higher green forage resulting in higher realization as compared to without biofertilizer inoculation and also found that highest green fodder and dry fodder yields were recorded with 100 per cent RDF + biofertilizers (Azotobacter + PSB). The balanced application of NPK fertilizers with lime and FYM helped in improving the crop productivity and growth of maize (Dutta *et al.,*2013). The study conducted by Shekhara *et al.,*2009 reported that application of 50% recommended dose of nutrients through inorganic fertilizer with 50 % organic nutrients through FYM recorded significantly higher green fodder yield (538.64 q/ha) and nutrient use efficiency (108.77%) in multicut fodder sorghum.

Karki *et al.* (2013) at New Delhi conducted an experiment on maize and reported that application of 120 kg N+10 t FYM per ha produced significantly higher plant height and dry matter production per plant over rest of the treatment combinations. Similarly, Kumar *et al.* (2005) at New Delhi reported that application of 120 kg N+26.2 kg P_2O_5+33.2 kg K_2O per ha combining with 10 t FYM per ha recorded significantly higher plant height and leaf area index of maize over chemical fertilizers alone. The study conducted by Sathish *et al.* (2011) at Kathalagere, India recorded higher maize yields with application 50 per cent N through FYM and 50 per cent NPK through inorganic fertilizers. Application of 75 per cent (NPK)+FYM (4.5 t/ha) + biofertilizer (*Azotobacter*+Phosphate solubilizing bacteria (PSB) proved to be superior as compared to other combinations including unfertilized control in increasing fodder yield and green biomass yield (Rasool *et al.,* 2015). The effect of inorganic and biofertilizers on Napier bajra hybrid grass at Coimbatore revealed that highest green (323.9 t/ha) and dry fodder (79 t/ha) were obtained with the application of biofertilizer mixture (*Azospirillium* + *Phosphobacterium*) along with 100 per cent recommended dose of N and P fertilizer together (Chellamuthu *et al.,.,,,* 2000).The study conducted by Sharma *et al.,*2009 at Jorhat, Assam found that application of 50 per cent recommended dose of fertilizers (RDF) along with vermicompost (2.5 t/ha) and FYM (2.5 t/ha) recorded the highest green forage (288.26 q/ha) and dry matter yields (68.621 q/ha) of oat crop. Similarly, application of 50 per cent RDF along with vermicompost (5 t/ha) and FYM (5 t/ha) gave significantly higher green fodder and dry matter yield than other treatments except 50 per cent RDF either with vermicompost or FYM @ 5 t/ha in fodder oat. The yield obtained with 100 per cent RDF was statistically at par with 50 per cent RDF with vermicompost or FYM @ 5 t/ha (Sheoran *et al.,* 2005).

It can be established from the study that organic fertilizers help in saving the cost incurred in inorganics besides maintaining the soil health.

Effect of integrated nutrient management on quality parameters of forage crops

As nitrogen is basic constituent of protein and with increase in rate of nitrogen application from organic manures and inorganic fertilizers along with biofertilizers, the nitrogen availability increased which resulted in enhanced protein content in fodder. Patel *et al.* (2018) observed that application of 80 kg N/ha and 40 kg P/ha along with Azotobacter + PSB significantly improved the crude protein and lowest crude fibre content in sandy loam soils of Gujarat which in turn resulted in better succulence and palatability. Yadav *et al.* (2007) at Anand (Gujarat) observed that application of 75 kg N through urea+25 kg N/ha through farm yard manure (FYM) increased dry matter yield and crude protein yield of sorghum by 18.6 and 20 per cent, respectively, over application of 100 kg N/ha through urea. Fodder quality parameters like juice percentage (26.2), dry matter content (25.6%), digestibility (48.7 %) and neutral detergent fibre content (61%) were recorded with application of 75 per cent recommended dose of N through inorganic sources+ 25 per cent through vermicompost (Singh *et al.,*2013). Also, the higher crude protein content of forage sorghum was found with the application of 75 kg N/ha through chemical fertilizer+25 kg N/ha through FYM or castor cake along with the combined inoculation with *Azotobacter chroococcum* (ABA-1) + *Azospirillum lipoferum* (ASA-1) by Yadav *et al.* (2007). Application of vermicompost 5 t/ha along with inoculation of Azotobacter @ 2 kg/ha gave the maximum dry matter and protein yields of 93.4 and 7.40 q/ha, respectively (Rawat and Agrawal 2010). Biofertilizer inoculation recorded higher dry matter and protein yields resulting in higher realization compared to no biofertilizer inoculation (Devi *et al.,* 2014, Patel *et al.,* 2010). In another study, protein and digestibility dry matter (DDM) yields increased by 14.9 and 1.9 %, respectively due to *Azospirillum* inoculation over no inoculation (Gupta *et al.,* 2007). The *Azospirillum* culture recorded 7.7 % higher crude protein yield over uninoculated control (Agrawal *et al.,* 2005). The maximum dry matter and crude-protein yields were recorded when forage sorghum is inoculated with *Azotobacter* + *Azospirillum* as compared to their individual inoculation or no inoculation (Yadav *et al.,* 2007). Godara *et al.* (2012) at Ajmer, Rajasthan found that application of N (80 kg/ha) and P (40 kg/ha) along with vermicompost (5 t/ha) recorded maximum dry matter and crude protein yields in oat crop. The increased crude protein yield was due to added supply of nutrients and well developed root system under balanced nutrient application.

FYM and inorganic fertilizer are known to have synergistic effect. Sometimes the FYM has supplementary and complimentary effect with inorganic fertilizer. Kalra and Sharma (2015) at Ludhiana, Punjab reported that application of 40 kg N/ha in conjunction with FYM (12.5 t/ha) produced equivalent crude protein in fodder maize compared to 120 kg N/ha alone. FYM (25 t/ha) alone produced crude protein equivalent to 12.5 t/ha FYM in combination with 80 kg N/ha. They further observed significantly higher IVDMD with application of FYM @ 25 t/ha than all the levels of nitrogen alone but at par with 80 kg N/ha in the presence of FYM @ 12.5 t/ha. The study conducted by Meena *et al.* (2018) at Avikanagar, Rajasthan found that application of 40 kg N/ha + 60 kg P_2O_5/ha along with bacterial inoculation (*Rhizobium*, *Azospirillium* and PSB) in cenchrus: cowpea in alternate paired rows had brought significant improvement in dry matter, crude protein content of over other treatments like control, bacterial inoculation, 40 kg N/ha, 60 kg P_2O_5/ha and 40 kg N + 60 P_2O_5/ha, respectively. Sharma (2009) conducted a study at Bikaner, Rajasthan and found that N levels increased the dry matter and crude protein yield significantly at each levels of sheep manure. He further reported that dry matter yield with 150 kg N/ha + 10 t/ ha sheep manure was at par with 150 kg N/ha alone and 100 kg N/ha + 10 t/ha sheep manure, but was significantly higher over rest of the N levels with or without sheep manure. Whereas, the difference in yields of crude protein at 100 or 150 kg N/ha along with 10 t/ha sheep manure were statistically at par but significantly greater than rest of the N levels with or without sheep manure application. Crude protein content was found to be increased significantly or tended to increase with an increase in the dose of FYM and nitrogen application (Kumar and Sharma 2002). Application of 50 per cent recommended dose of NP (40:20) along with vermicompost (5 t /ha) and FYM (5 t/ha) gave significantly higher dry matter and crude protein yields of sorghum than the other treatments (Kumar *et al.*,2004). Also, maximum crude protein (4.59 q/ha) and dry matter (60.6 q/ha) yields were obtained with application of 50 per cent RDF with 10 t/ha FYM and 100 per cent RDF, respectively. Similarly, crude protein and dry matter yields increased by 14.9 and 1.9 per cent, respectively, due to *Azospirillum* inoculation over no inoculation (Gupta *et al.*,2007). The application of 25 per cent N through FYM along with 75 per cent RDF and *Azotobacter* inoculation proved superior for dry matter yield over other combinations of organic and inorganic fertilizers in sorghum (Kumar *et al.*,2008). Application of 100 per cent of recommended dose of nutrients through inorganic fertilizer along with VAM recorded higher dry matter production (128.81 q/ha) and crude protein yield (6.34 q/ha). Patel *et al.* (2010) showed that application of 100 per cent of recommended dose of fertiliser along with FYM (10 t/ha) significantly increased the dry matter and crude protein yields of forage maize than other fertility levels tested in middle Gujarat conditions. The same treatment also recorded higher dry matter and crude protein content than 100 per cent RDF alone.

Conclusion:

Besides optimizing chemical fertilizer application, integrated nutrient management also enhanced forage quality in terms of higher macro and micronutrient concentrations. Application of inorganic fertilizers amended with different sources of organic manures in different proportions found to have a significant role to boost forage productivity and quality and maintain soil health. Higher maize and pearl millet yield recorded with application of 50 per cent N through FYM and 50 per cent NPK through inorganic fertilizers. Higher green herbage, dry matter yield and quality of oat can be obtained with integration of either vermicompost @ 5 t/ha or FYM @ 10 t/ha and *Azotobacter* with 75 per cent of recommended dose of fertilizer resulted in saving of 25 per cent chemical fertilizer. It can be concluded that combination of organic and inorganic nutrient sources gave significantly better results than when either were used alone. In the era of intensive agriculture, this review study advocates the positive relationship of integrated use of chemical and natural fertilizers for sustaining soil health and crop productivity.

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STUDY ON THE APPLICATION OF NITROGEN FERTILIZER ON QUALITY OF SUGARCANE

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Abstract:

A field experiment was conducted at irrigation cafeteria of Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore to study the impact of N fertilization on quality of sugarcane. There are five treatments viz., T_1- 161 kg N ha^{-1}, T_2- 195.5 kg N ha^{-1}, T_3- 230 kg N ha^{-1}, T_4- 264.5 kg N ha^{-1}, T_5- 299 kg N ha^{-1} with four replications. The variety used was Co 86032. The fertigation schedule predicted by Ravikumar *et al.* (2011) was used at fortnightly interval starting from 15th day to 180th day. The entire recommended dose of P @ 62.5 kg ha^{1} was applied as basal and K @ 112.5 kg ha^{-1} was given in ten splits. The soil and plant samples were collected at 60, 120,180,240,300 days after planting and at harvest for analyses and the results were statistically scrutinized. Application of N as urea fertilizer showed positive response up to 195.5 kg ha^{-1} and beyond this level there exists negative response. The N uptake, single cane weight, number of millable canes and water use efficiency is higher in the treatment which received N@195.5 kg ha^{-1}. It also enhanced the quality parameters viz., brix, sucrose, commercial cane sugar and purity per cent. Even though, the available nutrient content in soil, crop content and the uptake of nutrients are higher in the treatment which received N@ 299 kg ha^{-1}. The yield and quality parameters are declined at this level and the parameters are higher in the treatment which received N @ 195.5 kg ha^{-1}. Observed value for N uptake in the application of N @ 195.5 kg/ha closely followed the predicted N uptake from the model HYDRUS- 2D. With regard to B: C ratio the treatment that received N@195.5 kg ha^{-1} recorded the highest value of 3.63. Hence, this investigation has brought out the best nutrient management system using urea as an N source under fertigation as an effective and economic source for sugarcane.

Introduction:

Sugarcane is considered as one of the most important cash crops which plays a pivotal role in Indian Economy. A good crop considerably exhausts the available macro, secondary and micro nutrients from the soil. Therefore, mineral nutrition is one of the potential means of improving cane yield.

Nitrogen, the luminary input of sugarcane production is also a single factor which contributes more to agricultural production. Urea is the widely used nitrogenous fertilizer. Indian fertilizer industry is urea based and may remain as the main source of N for many years to come. The agronomic use efficiency of urea is abysmally low (around 20 to 40 per cent) under predominantly subtropical agriculture in India (Suri *et al.*, 2001). In India and China for example, recommended applications of N can be as high as 300 kg ha^{-1}, with the recommendations in the range of 150 – 200 kg ha^{-1} in a number of other countries.

In this context, fertigation can be a more efficient way of applying crop nutrients, particularly N, so that nutrient application rates can be reduced by minimizing the losses. It is commonly accepted that the efficiency of fertilizer use can be improved when it is applied by fertigation to most crops, including sugarcane (Ng Kee Kwong and Deville, 1994).

Excess application of N can also decrease the sugar content of cane. While there are recommendations for N application rates in conventional management systems, there is little information on what the optimum N rate should be for fertigated sugarcane. Continuing to apply the same N rates used in conventional management systems to fertigated sugarcane crops would probably result in lower N- use efficiency and increased losses of N to the environmnt. Hence, the outcome could be contrary to the desired benefits from adopting fertigation.

An experiment was therefore undertaken to study the influence of different N levels using urea as fertilizer source under fertigation following the fertigation schedule developed by Ravikumar *et al*. (2011) at fortnightly basis based on the plant assimilation curve by modelling the vadose zone using Hydrus 2- D software on yield and quality parameters in promising variety of Sugarcane.

Materials and Methods:

Field experiment was carried out at Irrigation cafeteria of Water Technology centre, TNAU, Coimbatore. The field is situated in the western zone of Tamil Nadu at 11° North latitude and 77° East longitude and at an altitude of 426.7 meters above MSL. The experiment was laid out with sugarcane var. Co 86032 in Randomized Block design with five treatments, replicated four times. The fertigation schedule is given below.

Fortnightly interval	T_1- 161 kg N ha^{-1}	T_2- 195.5 kg N ha^{-1}	T_3- 230 kg N ha^{-1}	T_4- 264.5 kg N ha^{-1}	T_5- 299 kg N ha^{-1}
1	2	2	2	2	2
2	6	7	9	10	11
3	6	7	9	10	11
4	9	11	13	14	17
5	9	11	13	14	17
6	10	12	14	17	19
7	28	34	40	46	52
8	28	34	40	46	52
9	28	34	40	46	52
10	28	34	40	46	52
11	7	9.5	10	11.5	13
Total	**161**	**195.5**	**230**	**264.5**	**299**

The optimal fertigation scheduling for urea was developed by Ravikumar *et al.* (2011) at fortnightly basis based on the plant assimilation curve by modelling the vadose zone using Hydrus 2- D software. Actually the fertigation schedule was developed for the ratoon crop. Since, this is a first crop, initially uniform dose was imposed and then a month later the actual schedule was followed. The soil type was sandy clay loam, being low in available N (225 kg ha^{-1}), medium in available phosphorus (16.1 kg ha^{-1}) and high in available potassium (525 kg ha^{-1}). Healthy two budded setts were planted in the furrows at 1.5 m spacing following "wet method" of planting. Nitrogen as urea, phosphorus (62.5 kg ha^{-1}) as single super phosphate and potassium as muriate of potash (112.5kg ha^{-1}) were applied. The variation in the Nitrogen dose was shown in all treatments but for the dosage of phosphorus, potassium and micronutrients were maintained at same for all the treatments. The entire quantity of Phosphorus @ 62.5 kg ha^{-1}was applied as a basal dose, while potassium was applied in thirteen splits. The micronutrient mixture of 50 kg ha^{-1} (formulations) were applied through fertigation as per the recommendation. All fertilizers were applied through fertigation using the automated fertigation unit.

Cropping, management practices and plant protection methods were followed as per TNAU crop production guide and the crop was harvested at 12 months. Cane yield was recorded and expressed as tones ha^{-1}. The juice samples at harvest were analysed for Brix, sucrose and purity through polarimeter and Commercial Cane Sugar (CCS) was worked out.

Results and Discussion:

Influence of N levels on Yield and juice quality

Among the doses of N, application of 195.5 kg ha^{-1} recorded the highest cane yield of 143.82 t ha^{-1} which is 17, 13.6, 10, 12 per cent higher than the treatment which received N @ 299, 264.5, 230, 161 kg ha^{-1} respectively (Table 1). It is evident from the present investigation that N application up to 200 kg ha^{-1} increased the yield linearly. But beyond that level, the yield of sugarcane reduced significantly. This was in line with the findings of Singh and Mohan (1994). Wiedenfeld and Enciso (2008) reported linear response on cane yield with the application of N through drip up to 180 kg ha^{-1}. This finding corroborates with present investigation result which shows linear response upto 195.5 kg ha^{-1}.

Table 1: Effect of N levels on the yield parameters of Sugarcane

Treatments	**Yield Parameters**		
	Cane yield (t ha^{-1})	**Number of Millable Cane (In thousands)**	**Single Cane Weight (Kg)**
T_1- N@161 kg ha^{-1}	126.3	74.25	1.43
T_2- N@195.5 kg ha^{-1}	143.8	83.00	1.63
T_3 N@230 kg ha^{-1}	129.5	75.03	1.38
T_4 N@264.5 kg ha^{-1}	124.3	75.50	1.18
T_5 N@299 kg ha^{-1}	119.1	74.95	1.30
Mean	128.6	76.55	1.38
SEd	**3.841**	**2.641**	**0.116**
CD (5%)	**8.461**	**5.819**	**0.255**

The juice extracted from cane assumes greater importance as it is directly related to the commercial output of sugarcane. The nature and composition of juice determine the quality of commercial cane sugar. Although the juice characteristics are mainly determined by the genetic makeup of the varietal characteristics, attempts are also being made to improve the quality parameters of juice by proper management practices.

The brix values, sucrose content and purity percentage determine the quality of cane. The cane quality is good if it contains 12- 13 per cent of sucrose and purity with minimum amount of non sugar. In the present study, the quality parameters were affected due to excess application of N fertilizer (Table 4).

The results revealed that the juice quality declined beyond the application of N @ 195.5 kg ha^{-1}. The possible reason for this might be, with increased dose of nitrogen and increased activity of enzymes, which is responsible for degradation of sucrose and changing into glucose and fructose This is in accordance with, Singh and Mohan (1994) but they reported the poor quality of juice beyond 300 kg N ha^{-1}. The differential N levels had significant effect on brix, sucrose and purity of sugarcane juices. The higher brix, sucrose and purity of sugarcane was obtained in the treatment which received N @ 195.5 kg ha^{-1} and the lowest content of the above said parameters were found in the treatment which received N @ higher dose i.e 299 kg ha^{-1}. Similar findings were reported by Singandhupe *et al*. (2008). Fritz (1974) and Wiedenfeld (1995) reported that during the ripening phase, an abundance of nitrogen in the plant is detrimental to sucrose accumulation and ultimately the sugar yield.

Conclusion:

Even though, the available nutrient content in soil, content and uptake of nutrients are higher in the treatment which received N @ 299 kg ha^{1}, the yield and quality parameters are declined at this level and the parameters are higher in the treatment which received N @ 195.5 kg ha^{-1}. The yield of Sugarcane increased progressively with the increasing N applications upto 195.5 kg ha^{-1}, and beyond that showed a declining trend. Also there was a adverse effect on the quality of the sugarcane juice beyond the level of 195.5 kg of N was observed. Hence, application of N through urea under the fertigation schedule starting from 15^{th} day to 180^{th} day in fortnightly interval will increase the cane yield and enhance the juice quality.

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FUTURISTIC VIEW OF LIVESTOCK FARM

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Introduction:

With urbanization and income increments, the demand of high quality, sustainable and safe livestock production is also increasing. A continuous increase in the demand of egg and meat has been observed all over the world (Vasant and Zhang, 2010). Due to irrational and over use of antibiotics, health issues for both animal and human are increasing day by day (Moudgil *et. al*., 2018). Nowadays, the environmental impact of the livestock rearing such as eutrophication potential, acidification potential, greenhouse gas emissions leading to global warming has also become a major issue. The hugely increasing livestock products demand is creating pressure on supply chain, environment and health safety issues.

Recently developed technologies in livestock can be used to combat this rising pressure. Such technological improvements provide easy and scientific livestock management. Now, the management conditions are changing quickly due to high-speed internet and smart phones (Neethirajan, 2020). Today, several industries have been transformed through machine learning (ML) and artificial intelligence (AI). Greater gains and efficiencies will be resulted livestock industry also by using such technologies (Wolfert *et. al.*, 2017).

Need for advanced technologies in livestock

- Limited land.
- Limited feed resources.
- Wide use of internet.
- Demand for livestock products.
- Disease outbreak.
- Lack of manual power.
- For maintenances of efficiency and quality of livestock products.
- For monitoring and forecasting the farm animal growth.
- For efficiently tackling parasitic diseases.

Different technologies in livestock include:

Machine learning

It is based on idea that machine can learn from data, identify patterns and make decisions with minimal human intervention. To apply mechanistic models in animal farming, we need to collect a large volume of diverse datasets. Some of them may include local weather data, air quality data, voice signals of animals, visual data of various animal movements and other such animal behavior data. In animal farming, mechanistic models have the potential to solve complex problems such as: identifying functional limiting factors, determining optimal nutrient composition of animal feed, evaluating animal management to evaluate performance (Ferguson, 2014).

Big data

Big data plays a key role in application of advanced technologies to animal farming practices and offers a solution to store vast amounts of data on a remote server. Advanced AI and ML algorithms can make use of this extensive data to analyze, predict and notify farmers in case there is something abnormal. It is storage of large volumes of textual, audio and video data. Storing and processing such vast amounts of data, every day, through the year is not possible with an ordinary computer. It will soon run out of storage and computing power.

Sensor

A sensor can be defined as a device which measures or detects abiological, chemical, physical or mechanical property or a combination of these properties, records and collects the data for interpretation by a human or a machine. It is real time data capturing. Based on the livestock farming market needs, the sensor technologies can be classified as (Neethirajan, 2020):

1. Based on different species
2. Sensors for precision livestock farming such as milking robots.
3. Functional process based such as weight estimates, animal behaviour, wearable vs non-wearable.
4. Hardware sensors including camera or vision sensors, temperature sensor, radio frequency identification tags.

Expert system

"Knowledge Based Systems" is a term used to designate the Expert system. Its function is to combine knowledge gained through experiments and experience of subject matter specialists' intuitive skills to assist farmers in coming at better decision. Breeding of animals, management of animals shed, animals milking, health management, cultivation of animal's fodder and feeding are some of the important areas where expert system can provide their services effectively and efficiently.

Such system requires hierarchical classification and an amalgam of various data sets including pictures, description of text file etc. "Animal Health Information System'' is an example of one of the expert systems made by IVRI, Izatnagar for monitoring animals health and management practices. This system operates only in English language. "Health information system for dairy animals" is another expert system, but this operates in Marathi language. This is a boon for the farmers of Maharashtra (Phand et al. 2009).

Types of expert system

1. Information System

Information system is web based static information wherein all the technological and complementary information are pooled and loaded. It is a ready and user-friendly navigation with image-based presentation. Information system helps in characterization of livestock and feed resources, animal disease surveillance and real time information of livestock products supply.

Information system on organic livestock farming developed by IVRI:

Geographic Information System is a computerized database management system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to location. Global positioning system and remote sensing are widely used techniques of information system.

National Animal Disease Referral Expert System is a dynamic geographic information system and remote sensing-enabled expert system that captures an incidence of 13 economically important livestock diseases from all over the country and also provides livestock disease forecasting.

Mapping of livestock farms under 20th livestock census has been done through **BHUMIKA** app. Assessment of methane emission from livestock with the help of GIS has been carried out by Shilpi *et. al.,* 2018. Ranade and Mishra, (2015) have proposed **Web-GIS based Livestock Information Management System (WGLIMS)** that is helpful to collect, analyze, model, visualize and disseminate data available on livestock in India. **Animal Health Monitoring System** based on sensor is proposed in Gujrat (Bhavsar et. al., 2012) which try to extend health care from traditional veterinary hospital setting to wireless sensor network based remotely health monitoring and diagnosis system for animal.

Decision Support System

Decision Support System (DSS) is a computer-based and knowledge-based system that support decision making activities. A decision is a choice between alternatives based on estimates of the values. For livestock, mostly "data-driven" or "knowledge-driven" DSS are available. Historical or current data is used for knowledge acquisition in decision support system.

(Devi *et. al.,* 2019) proposed a unique buffalo behavior decision support system of estrus detection for the problem of silent estrus in buffaloes through various acoustic features of vocalization.

National Animal Disease Reporting System

It is a web-based information technology system for disease reporting from States and Union Territories with the aim to record, monitor livestock disease situation and to initiate the preventive and curative action during disease emergencies.

Mammadova and Keskin, 2015) proposed a model for subclinical mastitis detection method for Holstein cows. (Panchal *et. al.,* 2016) created a cost-effective to classify healthy and mastitis Murrah buffaloes.

Precision livestock farming

Precision livestock farming (PLF) has the objective to create a management system based on continuous automatic real-time monitoring. It improves the efficiency and gains in livestock industry in terms of animal health, reproduction and production and environmental impacts (Berckmans, 2014). This system is completely rely upon sensors which collect a variety of information for individual recognition and behaviour analysis. Advanced data processing techniques make it possible to analyse animal behaviour continuously, automatically, accurately and in real time (Van Hertem *et al.,* 2017 and Valletta *et al.,* 2017). Different activities under precision livestock farming includes animal identification, balanced rationing, microclimate management. Warning sign is received by farmer if something is wrong.

Key elements in precision livestock farming

1. **Identification systems**

Electronic identification (EID) systems are a key component of precision livestock farming. It includes ear tagging, ruminal bolus with EID which are inserted into stomach. Injectable sub-cutaneous electronic identification technique is also used in various places. Radio-frequency identification (RFID) helps in easy identification of animals. **Maharashtra Animal Identification and Recording Authority (MAIRA)** is the initiative of government using EID. Data is stored for decision making processes.

2. **Accelerometers and Pedometers**

A system that measures movement in terms of the direction and speed of the sensor is attached to the foot, neck or head of the animal to register movement patterns linked to behaviours such as resting, grazing, moving and running/playing or lameness.

3. **Pedometer**

Wireless sensor network-based precision animal management system known as **Moosense** was developed at ICAR-NDRI, Karnal (Sarangi et al. 2014). Several parameters such as ambient temperature and humidity, nutrient intake, and activity can be monitored simultaneously (Mohanty et al. 2010, Sarangi et al. 201

4. Mating detection systems

A centralized computer is used for data transmission of true and false mating. This system has currently passed the research phase and is being tried in field conditions for commercial production (Alhamada *et al.*, 2017).

5. Weighting Crates

Communicates with the animals' electronic identification tag and record the data.

6. Pasture management

Virtual fencing is also used for extensive animal management.

7. Drones

Infra-red sensors and multi spectrum high definition cameras are used to monitor grazing and resting behaviour.

8. Robot milking

Robot milking is highly advanced technology for clean milk production. It is common in big dairy farms of developed countries. A sensor-controlled arm is used for feeding the animal while milking. Milk is tested for incidence of mastitis on daily basis. Moreover, milk contents are also quantified for each animal (Göncü and Güngör, 2018).

Drawbacks of advanced technology in livestock

Technology is very expensive. Moreover, it requires technical expertise and qualified and trained workers. It may create privacy issues. Interruption in signals may cause jamming of whole system. Antenna patterns affect the RFID performance.

Conclusion:

Livestock rearing is a very cumbersome and 24*7 effort demanding business. As this requires continuous farm activities. In practical world, it is very difficult for the veterinary officers, veterinary practitioners, animal nutritionist and animal rearing farmers to continuously visit animal farms. These innovative technologies can generate data which can be accessed on remote locations which ultimately leads to lowering the farming cost and improved farm performance, which are the prime objectives of every livestock farmer.

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FARM MANAGEMENT AND AGRIBUSINESS STRATEGIES

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Abstract:

This book chapter explores various aspects of modern agricultural practices and business strategies. It begins by discussing the fundamental principles of farm management, emphasizing the importance of efficient resource utilization, cost control, and production optimization. Farm planning and analysis are then introduced as essential tools for achieving long-term sustainability and profitability. Financial management in agriculture is addressed, focusing on budgeting, financial analysis, and risk management. Marketing and market analysis are discussed to help farmers understand consumer demands and develop effective strategies for product placement and pricing. The chapter discusses agribusiness strategies, highlighting the need for diversification and value-added products to enhance profitability. Sustainable agriculture and conservation practices are explored as vital components of modern farming, emphasizing the importance of environmentally friendly methods. Human resource management in agriculture is discussed, recognizing the significance of skilled labour and effective team management. Finally, the chapter looks at future trends and challenges in farm management and agribusiness, such as technological advancements, changing consumer preferences, and global market dynamics. Overall, it provides a comprehensive overview of essential concepts and strategies for successful farming and agribusiness management.

Keywords: Agribusiness strategies, farm management, financial management, human resource management and sustainable agriculture.

Introduction:

Farm management and agribusiness strategies are critical components of modern agriculture that play a pivotal role in ensuring the sustainability and profitability of farming operations (Adenle *et al.*, 2017; Chia *et al.*, 2019). In this chapter, we will discuss various aspects of farm management and agribusiness strategies, providing a comprehensive overview of the principles and practices that are essential for success in the agricultural sector (Chen *et al.*, 2016; Singh and Mishra, 2023). The chapter begins by explains the fundamental principles of farm management, emphasizing the importance of effective decision-making, resource allocation, and overall planning in agricultural enterprises (Paustian *et al.*, 2015). It explores the intricacies of farm planning and analysis, showcasing how meticulous planning can lead to improved yields, cost-efficiency, and long-term sustainability (Bannikova *et al.,* 2015).

Financial management in agriculture is a critical aspect discussed in the chapter, highlighting the importance of budgeting, financial analysis, and risk management for successful farm operations (Bensemann and Shadbolt, 2015). Readers will gain an understanding of how financial strategies can significantly impact the viability of agricultural enterprises (Barnard *et al.,* 2020). The chapter also discuss the marketing and market analysis within the agricultural sector. It elucidates the strategies employed to identify market opportunities, develop marketing plans, and effectively reach target consumers (Singh and Mishra, 2023; Mkhabela, 2018). In-depth insights into market analysis help readers make informed decisions regarding their agricultural products and services (Keshelashvili, 2018). Agribusiness strategies are a central focus of this chapter, exploring how businesses in the agricultural industry can leverage their resources, technology, and innovation to achieve competitive advantages. The chapter sheds light on the important strategies that agribusinesses employ to enhance their market position and profitability (Petrick *et al.,* 2017; Anwarudin *et al.,* 2020).

Sustainable agriculture and conservation practices are given due consideration, emphasizing the increasing importance of environmentally responsible farming methods (Mishra and Singh, 2023; Gunarathne and Lee, 2020). Readers will learn about the benefits of sustainable practices in ensuring long-term productivity while safeguarding the environment (Lai *et al.,* 2018). Human resource management in agriculture is another critical aspect covered in the chapter, addressing the challenges and strategies associated with hiring, training, and retaining skilled labour within the agricultural workforce (Shadbolt, 2016). The chapter concludes by exploring future trends and challenges in farm management and agribusiness (Syromyatnikoy *et al.,* 2020). It provides valuable insights into the evolving landscape of the agricultural industry, including technological advancements, changing consumer preferences, and global market dynamics (Carrer *et al.*, 2017).

Farm Management and Agribusiness Strategies offers a comprehensive overview of the major elements essential for success in the world of agriculture (Lechenet *et al.,* 2016). Whether you are a farmer, agricultural entrepreneur, or a student looking to gain a deeper understanding of this vital industry, this chapter will provide you with the knowledge and tools needed to navigate the complex and ever-changing agricultural landscape (Amfo and Ali, 2020; Mishra and Singh, 2023).

Farm management principles

Farm management is the strategic and systematic process of planning, organizing, and controlling the various resources and activities on a farm to achieve its goals efficiently and effectively. It involves making informed decisions to optimize the use of resources such as land, labour, capital, and technology to maximize agricultural production, profitability, and sustainability (Babu *et al.*, 2016).

1. The role of farm managers

Farm managers play a pivotal role in the success of agricultural operations. Their responsibilities encompass a wide range of tasks, including:

- **Planning:** Developing short-term and long-term goals for the farm, setting production targets, and formulating strategies to achieve them.
- **Organizing:** Structuring the farm's resources, including land, labour, machinery, and finances, to ensure smooth operations and goal attainment.
- **Directing:** Supervising farm workers, providing guidance, and ensuring that everyone understands their roles and responsibilities.
- **Controlling:** Monitoring the performance of the farm, comparing it to established benchmarks, and taking corrective actions when necessary.
- **Decision-making:** Making informed decisions related to crop selection, livestock management, marketing, and investments.
- **Risk management:** Identifying potential risks, both internal and external, and implementing strategies to mitigate them.

2. Major principles of effective farm management

Effective farm management relies on several major principles to guide decision-making and ensure success. These principles encompass various aspects of running a farm efficiently and sustainably:

Planning:

- **Goal setting:** Clearly define the farm's objectives, whether they are focused on increased production, profit maximization, or sustainability.
- **Budgeting:** Develop detailed financial plans that outline income, expenses, and investments required to achieve the goals.
- **Crop rotation and diversification:** Plan crop rotations and diversify production to optimize soil health and reduce pest and disease pressure.
- **Seasonal planning:** Create a seasonal calendar that outlines planting, harvesting, and other critical activities to avoid bottlenecks and optimize resource use.

Decision-making:

- **Data-driven decisions:** Collect and analyse relevant data, such as market trends, weather forecasts, and production records, to make informed choices.
- **Risk analysis:** Assess the potential risks and benefits of various decisions to choose strategies that align with the farm's goals and risk tolerance.
- **Adaptability:** Be prepared to adapt to changing circumstances and adjust decisions as needed.

Resource allocation:

- **Labour management:** Efficiently allocate labour resources to different tasks based on their skill sets and the needs of the farm.
- **Land use planning:** Optimize land use through proper crop selection, rotation, and efficient spacing.
- **Capital investment:** Allocate financial resources wisely, investing in equipment, technology, and inputs that provide the greatest return on investment.

Risk management:

- **Insurance:** Consider insurance options to protect the farm against unforeseen events such as natural disasters or market fluctuations.
- **Diversification:** Spread risks by diversifying both in terms of crops or livestock and marketing strategies.
- **Contingency planning:** Have contingency plans in place for potential crises, such as droughts or disease outbreaks.

Effective farm management involves a holistic approach that integrates planning, decision-making, resource allocation, and risk management. Farm managers play a crucial role in implementing these principles to ensure the farm's productivity, profitability, and long-term sustainability (Osumba *et al.*, 2021).

Farm planning and analysis

1. Farm goals and objectives

Setting clear and well-defined goals and objectives is the foundation of successful farm planning. Farm owners must consider both short-term and long-term aspirations. These objectives may include increasing crop yields, expanding livestock operations, achieving sustainability goals, and improving financial stability (Mishra and Singh, 2023).

2. Farm planning process

- **Land use planning:** Land is a finite resource, and efficient land use is critical for farm success. The land use planning process involves assessing the farm's current land resources and determining the most appropriate uses for each parcel. This includes allocating land for crop cultivation, pasture, animal housing, and infrastructure development.

- **Crop and livestock selection:** Selecting the right crops and livestock species is essential for maximizing farm productivity and profitability. This involves considering factors such as soil type, climate, market demand, and the farm's resources and capabilities. Crop rotation and diversification can also be part of this planning phase to improve soil health and reduce pest pressure.
- **Budgeting and financial planning:** Financial planning is a crucial aspect of farm management. Farmers need to create detailed budgets that account for expenses such as seed, fertilizer, labour, equipment, and marketing costs. Financial planning also includes revenue projections based on expected crop and livestock yields, as well as market conditions. These budgets help in making informed decisions and ensuring the farm's economic viability.

3. Risk analysis and mitigation strategies

Farming is inherently risky due to factors like weather fluctuations, pests, and market volatility. Farmers must conduct risk assessments to identify potential threats to their farm's success. Once risks are identified, mitigation strategies should be developed to minimize their impact (Fernando, 2020). This may involve diversifying crops, investing in insurance, implementing pest control measures, or adopting climate-resilient farming practices.

4. Sustainable farming practices and environmental considerations

Sustainability and environmental stewardship are increasingly important aspects of modern farming. Farmers should integrate sustainable farming practices into their plans to ensure the long-term health of their land and minimize negative environmental impacts (Zylbersztajn, 2017). This includes:

- **Soil health management:** Implementing practices like cover cropping, reduced tillage, and organic matter addition to improve soil fertility and structure.
- **Water management:** Implementing efficient irrigation techniques, reducing water wastage, and preventing soil erosion to protect water resources.
- **Biodiversity conservation:** Creating habitats for beneficial insects and wildlife, promoting crop diversity, and reducing the use of harmful chemicals.
- **Energy efficiency:** Adopting energy-efficient technologies and practices to reduce the farm's carbon footprint.

- **Waste reduction:** Developing strategies to minimize waste generation and promote recycling and composting.

By incorporating these sustainable practices into their farm planning, farmers not only protect the environment but also enhance their farm's resilience and long-term viability in an increasingly unpredictable world.

Financial management in agriculture

1. Importance of financial management in agriculture

Financial management plays a critical role in the success and sustainability of agricultural enterprises. It involves the planning, organizing, monitoring, and controlling of financial resources to achieve the farm's goals. Some major aspects of its importance:

- **Resource allocation:** Financial management helps in allocating resources efficiently, ensuring that capital, labour, and land are used optimally to maximize productivity and profitability.
- **Risk management:** It aids in identifying and mitigating financial risks such as market fluctuations, climate-related risks, and unexpected expenses.
- **Long-term planning:** Financial management allows farmers to plan for the long term, including investments in new equipment, technology, and infrastructure, ensuring the farm's competitiveness in the future.
- **Sustainability:** Proper financial management ensures that farming practices are sustainable, preventing over-exploitation of resources and protecting the environment.

2. Financial record-keeping and analysis

- **Record-keeping:** Maintaining accurate financial records is essential. This includes income statements, balance sheets, and cash flow statements, which provide insights into the farm's financial health.
- **Analysis:** Regular analysis of financial records helps identify trends, strengths, and weaknesses. Farmers can make informed decisions based on this analysis, adjusting their operations as needed.

3. Profitability and cash flow management

- **Profitability:** Assessing profitability involves calculating the return on investment for various farm activities. It helps determine which crops or livestock are most profitable and where adjustments are needed to improve margins.
- **Cash flow management:** Managing cash flow is crucial to ensure that there is enough liquidity to cover daily operational expenses, repay debts, and invest in necessary equipment or inputs.

4. Accessing farm finance and investment options

- **Capital needs:** Financial management involves assessing the farm's capital needs, including short-term working capital and long-term investments. Farmers can explore various financing options such as loans, grants, or partnerships to meet these needs.
- **Investment decisions:** Evaluating potential investments in land, machinery, technology, or diversification requires a thorough financial analysis to determine the expected returns and risks.

5. Tax planning for agricultural businesses

- **Tax compliance:** Understanding and complying with tax regulations specific to agriculture is crucial. This includes income tax, property tax, and agricultural exemptions that may apply.
- **Tax efficiency:** Tax planning involves strategies to minimize tax liability while adhering to legal requirements. This may include taking advantage of deductions, credits, and depreciation allowances.
- **Succession planning:** Planning for the transfer of the farm to the next generation or selling it involves careful tax planning to minimize tax consequences.

Financial management is integral to the success of agricultural businesses. It encompasses various aspects, from record-keeping and analysis to accessing finance and planning for taxes (Junior *et al.*, 2019). Farmers who prioritize sound financial management practices are better equipped to navigate the challenges and uncertainties of modern agriculture while ensuring long-term sustainability and profitability (Tiwari *et al.*, 2023).

Marketing and market analysis

1. Agricultural markets

Agricultural markets are a fundamental aspect of running a successful farm operation. Farmers need to comprehend the dynamics of supply and demand, pricing mechanisms, and the factors that influence market trends. This knowledge enables them to make informed decisions about what to grow or raise, when to sell, and to whom (Krissman, 2021).

- **Market dynamics:** Familiarize yourself with how agricultural markets function, including the role of intermediaries, transportation, and distribution channels.
- **Supply and demand:** Analyse the current supply and demand for your agricultural products. Understand how fluctuations in these factors affect prices and your profitability.
- **Price analysis:** Regularly monitor commodity prices, both locally and globally, to anticipate price movements and make timely selling decisions.

2. Market research and analysis

Conducting thorough market research and analysis is crucial for making informed business decisions and staying competitive in the agricultural industry.

- **Data collection:** Gather data on consumer preferences, trends in the agricultural industry, and competitors in your market.
- **SWOT analysis:** Perform a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to identify your farm's competitive advantages and areas for improvement.
- **Market segmentation:** Divide your target market into segments based on factors like demographics, geography, and behaviour to tailor your marketing efforts effectively.

3. Marketing strategies for farm products

Effective marketing strategies is essential for promoting your farm products and reaching your target audience.

- **Product differentiation:** Highlight the unique qualities of your products, such as organic certification, sustainability practices, or special breeding techniques.
- **Online presence:** Establish a strong online presence through a website and social media to showcase your products and engage with potential customers.
- **Content marketing:** Create valuable content, such as blog posts, videos, or recipes, that educates and informs consumers about your products and the agricultural industry.

4. Value-added products and branding

Creating value-added products and building a strong brand identity can set your farm apart from competitors and increase your profitability.

- **Value-added products:** Explore opportunities to transform raw agricultural products into value-added items, such as jams, cheeses, or craft beverages.
- **Branding:** Develop a unique and memorable brand identity that reflects your farm's values and mission. This includes a compelling logo, packaging, and messaging.
- **Quality assurance:** Implement quality control measures to consistently deliver high-quality products that meet or exceed customer expectations.

5. Building successful customer relationships

Establishing and maintaining positive relationships with customers is vital for long-term success in agriculture.

- **Customer engagement:** Interact with customers through social media, email newsletters, or in-person events to build a loyal customer base.
- **Feedback and improvement:** Encourage customer feedback and use it to continuously improve your products and services.

- **Customer service:** Provide excellent customer service by addressing inquiries, resolving issues, and ensuring a smooth purchasing experience.

Mastering marketing and market analysis in agriculture involves a multifaceted approach that encompasses understanding market dynamics, conducting thorough research, developing effective strategies, creating value-added products, and nurturing customer relationships. By excelling in these areas, farmers can maximize their profitability and sustainability in a competitive industry (Goedde *et al.,* 2015).

Agribusiness strategies

1. Agribusiness

Agribusiness refers to the entire spectrum of agricultural activities involved in the production, processing, distribution, and marketing of agricultural products and services. It encompasses both the traditional farming practices and the modern industrial aspects of agriculture, emphasizing the economic and business-oriented aspects of the agricultural sector (Kumar *et al.*, 2023).

Agribusiness involves a complex network of activities, from cultivation and harvesting to transportation, processing, packaging, and selling of agricultural products. It also includes related services such as finance, insurance, research and development, and technology adoption (Singh and Mishra, 2023). In essence, agribusiness is a holistic approach to agriculture that combines farming with various business functions to enhance efficiency, productivity, and profitability (Gagalyuk, 2017).

2. The integration of technology in agribusiness

- **Precision agriculture:** Precision agriculture involves the use of advanced technologies like GPS, drones, and sensors to optimize farming practices. Farmers can gather real-time data on soil conditions, weather patterns, and crop health, enabling precise decision-making and resource allocation.
- **Biotechnology:** Biotechnology has revolutionized agriculture with genetically modified crops (GMOs) and advanced breeding techniques. These technologies enhance crop yields, resistance to pests and diseases, and nutritional content.
- **Farm management software:** Farmers utilize farm management software to track inventory, monitor crop growth, manage finances, and plan planting and harvesting schedules efficiently.
- **Internet of Things (IoT):** IoT devices are used in agribusiness to collect data on machinery performance, soil moisture, and livestock health. This data helps in making informed decisions and optimizing resource usage.

3. Supply chain management in agriculture

Effective supply chain management is crucial in agribusiness to ensure the seamless flow of products from farms to consumers. Major aspects of supply chain management in agriculture include:

- **Procurement:** Sourcing quality seeds, fertilizers, and equipment at competitive prices.
- **Production:** Managing farm operations efficiently, including crop cultivation, animal husbandry, and pest control.
- **Harvesting and post-harvest handling:** Efficient harvesting techniques and proper storage and transportation of crops to minimize losses.
- **Processing and value addition:** Transforming raw agricultural products into marketable goods, such as turning tomatoes into tomato sauce.
- **Distribution and marketing:** Ensuring timely delivery of products to wholesalers, retailers, or consumers while adhering to quality standards.
- **Consumer feedback:** Collecting and analysing consumer feedback to improve product quality and meet changing demands.

4. Agribusiness models and case studies

- **Contract farming:** Contract farming is a partnership between farmers and agribusiness companies, where farmers agree to produce specific crops or livestock as per predefined terms and conditions. Agribusiness companies provide farmers with inputs, technical support, and a guaranteed market for their products. This model reduces production risks for farmers and ensures a consistent supply for companies. A notable example is the contract farming initiatives by companies like Nestlé and PepsiCo with potato farmers.
- **Cooperatives and farmer organizations:** Cooperatives and farmer organizations are collective efforts by farmers to pool resources, share knowledge, and access markets collectively. These entities empower small-scale farmers by giving them bargaining power in the market. An example is the Indian dairy cooperative Amul, which has transformed the lives of millions of dairy farmers.
- **Agtech startups and innovation in agribusiness:** The emergence of agtech startups has brought innovation to agribusiness:
  a) **FarmLogs:** This startup offers a digital platform for farmers to monitor and manage their crops, helping them make data-driven decisions.
  b) **Indigo Agriculture:** Indigo utilizes microbiology and data science to improve crop yields and reduce the environmental impact of farming.

c) **Farmers Business Network (FBN):** FBN provides farmers with data insights and a marketplace for agricultural inputs, fostering transparency and cost savings.

d) **AeroFarms:** AeroFarms is revolutionizing indoor vertical farming with cutting-edge technology, reducing water usage and enabling year-round crop production.

Agribusiness strategies continually evolve as technology advances and the global agricultural landscape changes. Adapting to these changes is crucial for the sustainability and profitability of the agriculture sector (Mishra and Singh, 2023; Otache, 2017).

Sustainable agriculture and conservation practices

1. Importance of sustainability in farming and agribusiness

Sustainability in farming and agribusiness has become a critical concern in recent years due to the escalating challenges posed by climate change, population growth, and resource depletion (Clay and Feeney, 2019). The significance of sustainability in this context cannot be overstated, as it directly affects our ability to meet the growing global demand for food while safeguarding the environment for future generations (Amirova *et al.,* 2020).

- **Environmental preservation:** Sustainable farming practices ensure the preservation of natural resources, such as soil and water. This is crucial for maintaining the long-term viability of agricultural operations and minimizing the negative environmental impacts, including soil erosion, water pollution, and habitat destruction.
- **Economic viability:** Sustainable agriculture is economically advantageous, as it often leads to reduced production costs, increased efficiency, and enhanced market opportunities. Farmers who adopt sustainable practices can benefit from improved crop yields, reduced input costs, and access to premium markets that value environmentally friendly products.
- **Social responsibility:** Ethical and socially responsible farming practices promote fair labour conditions, community engagement, and equitable distribution of resources. This not only enhances the well-being of farm workers but also fosters stronger, more resilient rural communities.

2. Sustainable agriculture practices

2.1 Organic farming:

Organic farming is a cornerstone of sustainable agriculture. It emphasizes the use of natural methods to maintain soil fertility and manage pests and diseases. Major features of organic farming include:

- **No synthetic chemicals:** Organic farms avoid the use of synthetic pesticides, herbicides, and fertilizers, relying instead on natural alternatives.

- **Crop rotation:** Farmers rotate crops to improve soil health and disrupt pest cycles.
- **Composting:** Organic matter is composted to enrich soil with nutrients and improve its structure.
- **Biodiversity:** Organic farms often promote biodiversity by planting cover crops and providing habitat for beneficial insects and wildlife.

2.2 Precision agriculture:

Precision agriculture involves the use of technology, data, and precise management practices to optimize resource use and increase productivity. It includes:

- **GPS technology:** GPS-guided machinery allows for precise planting, fertilizing, and harvesting, reducing waste and resource overuse.
- **Data analytics:** Farm data is collected and analysed to make informed decisions about irrigation, nutrient application, and pest control.
- **Variable rate technology:** This enables the adjustment of inputs based on variations within a field, leading to more efficient resource utilization.

2.3 Crop rotation and diversification:

Crop rotation and diversification are practices that reduce the risk of soil degradation, pest outbreaks, and nutrient depletion. These practices involve:

- **Alternating crops:** Planting different crops in succession helps break disease and pest cycles while replenishing soil nutrients.
- **Intercropping:** Growing multiple crops in the same field simultaneously promotes biodiversity and reduces susceptibility to pests and diseases.
- **Cover crops:** Planting cover crops during fallow periods prevents soil erosion, improves soil structure, and adds organic matter.

2.4 Conservation strategies and responsible land management

Sustainable agriculture extends beyond crop production and includes responsible land management to protect ecosystems and natural habitats. Major strategies include:

- **Reducing erosion:** Implementing erosion control measures such as contour farming, terracing, and buffer strips to prevent soil loss and protect waterways from sedimentation.
- **Water management:** Efficient water management practices like drip irrigation, rainwater harvesting, and the use of drought-resistant crops help conserve this precious resource.
- **Habitat preservation:** Setting aside areas for wildlife and maintaining natural habitats within agricultural landscapes fosters biodiversity and enhances ecosystem services.

- **Agroforestry:** Integrating trees and woody shrubs into farming systems improves soil fertility, sequesters carbon, and provides additional income sources through timber and fruit production.
- **Soil conservation:** Soil testing, nutrient management plans, and the use of cover crops all contribute to preserving and improving soil health.

Sustainable agriculture and conservation practices are essential for the long-term viability of farming and agribusiness. These practices not only ensure food security but also protect the environment, promote economic stability, and uphold social responsibility in agriculture (Micheels *et al.,* 2017). Adopting sustainable practices is crucial for meeting the challenges of the future while preserving our planet's natural resources (Mishra and Mishra, 2023).

Human resource management in agriculture

1. Farm labour and workforce

Effective human resource management is crucial in agriculture as it directly impacts the productivity and success of a farm. Managing farm labour involves several major components:

- **Recruitment and hiring:** Identifying and selecting the right candidates with the necessary skills and work ethic is essential. Farm managers need to consider factors such as seasonal labour needs, skill requirements, and local labour availability.
- **Workforce planning:** Developing strategies to ensure that the workforce is appropriately sized and structured to meet the demands of the farm operation. This includes managing full-time, part-time, and seasonal workers.
- **Employee retention:** Creating a positive work environment, offering competitive wages, and providing opportunities for advancement can help retain skilled workers and reduce turnover.
- **Safety and health:** Ensuring the safety and well-being of farm workers is a legal and ethical responsibility. Implementing safety protocols, providing training, and maintaining equipment in good working condition are vital aspects of this.

2. Training and skill development for agricultural workers

Continuous training and skill development are essential in the agriculture sector to keep the workforce competitive and adaptable. Major points include:

- **Training programs:** Developing and implementing training programs that cover various aspects of farming, including crop management, machinery operation, and pest control.
- **Skill enhancement:** Encouraging employees to acquire new skills and stay updated with the latest agricultural practices, technologies, and techniques.

- **Onboarding:** Providing comprehensive orientation for new hires to ensure they understand farm-specific practices, safety protocols, and expectations.

3. Labour laws and regulations in agriculture

Compliance with labour laws and regulations is imperative in agriculture to avoid legal issues and maintain ethical standards:

- **Fair labour standards:** Understanding and adhering to laws related to minimum wage, overtime, child labour, and other employment standards.
- **Worker protection:** Ensuring compliance with laws related to worker safety, including pesticide handling and exposure regulations.
- **Immigration laws:** Complying with immigration laws when hiring foreign agricultural workers.

4. Building a strong farm team and leadership

Strong leadership and teamwork are vital for a farm's success:

- **Leadership development:** Identifying potential leaders within the farm and providing opportunities for growth and leadership training.
- **Team building:** Promoting effective communication and collabouration among farm workers to enhance productivity and job satisfaction.
- **Succession planning:** Developing a plan for transitioning farm management and leadership to the next generation to ensure the farm's continuity.

Human resource management in agriculture encompasses a wide range of activities, from hiring and training to compliance with labour laws and building a strong farm team. Effective management in these areas is vital for the sustainability and success of agricultural operations (Nishad *et al.*, 2023).

Future trends and challenges in farm management and agribusiness

1. Emerging technologies in agriculture

The agriculture industry is rapidly evolving with the integration of advanced technologies:

- **Precision agriculture:** Utilizing data-driven technologies such as GPS, drones, and sensors to optimize farming practices, enhance crop yields, and reduce resource waste.
- **Artificial intelligence:** Implementing AI for crop monitoring, disease detection, and decision-making processes to increase efficiency and reduce human error.
- **Robotics and automation:** Incorporating robotics for tasks like planting, harvesting, and weeding, which can improve labour efficiency and reduce costs.

2. Climate change and its impact on farming

Climate change poses significant challenges to agriculture:

- **Extreme weather events:** Preparing for and mitigating the impact of more frequent and severe weather events, such as droughts, floods, and heatwaves.
- **Adaptation strategies:** Developing and adopting climate-resilient crop varieties and farming practices to ensure food security in changing conditions.

3. Global food security challenges

Ensuring a stable and secure food supply on a global scale is a pressing issue:

- **Population growth:** Meeting the demands of a growing world population while maintaining sustainable farming practices.
- **Distribution and access:** Addressing issues related to food distribution and access, especially in underserved regions.
- **Food waste reduction:** Implementing strategies to reduce food waste throughout the supply chain.

4. Regulatory and policy changes in the agricultural sector

Government policies and regulations can significantly impact farm management and agribusiness:

- **Environmental regulations:** Adapting to and complying with regulations related to water use, land conservation, and environmental protection.
- **Trade policies:** Navigating changes in trade agreements and tariffs that can affect market access and pricing.
- **Subsidies and support:** Staying informed about government subsidies, grants, and support programs that can assist in farm management and sustainability efforts.

The future of farm management and agribusiness will be shaped by emerging technologies, the challenges posed by climate change, efforts to ensure global food security, and regulatory and policy changes (Nematollahi *et al.*, 2021). To thrive in this dynamic environment, stakeholders in the agricultural sector must remain adaptable, innovative, and committed to sustainable practices (Salvini *et al.*, 2018).

Conclusion:

Overall, this chapter has discussed the various aspects of farm management and agribusiness strategies, emphasizing the importance of sound principles and practices in this field. It is evident that farm management principles serve as the foundation upon which successful agribusinesses are built. Farm planning and analysis enable farmers and agribusiness owners to make informed decisions and optimize their resources. Financial management plays a crucial role in ensuring the profitability and sustainability of agricultural operations, while marketing and market analysis are essential for identifying opportunities and creating competitive advantages. Agribusiness strategies encompass a wide range of approaches, from diversification to vertical integration, all aimed at maximizing profits and minimizing risks. Sustainable agriculture and conservation practices are increasingly important in today's world, as they not only protect the environment but also ensure the long-term viability of agricultural enterprises. Human resource management is critical for fostering a productive and motivated workforce in agriculture. As we look to the future, there are various trends and challenges that will shape the landscape of farm management and agribusiness. These include technological advancements, changing consumer preferences, climate change, and global market dynamics. Successful farmers and agribusiness owners will need to adapt to these challenges and continue to embrace innovative practices to thrive in the ever-evolving agricultural sector.

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AGNIHOTRA: ASHES TO YIELD APPROACH FOR CLEAN ENVIRONMENT AND SUSTAINABLE AGRICULTURE

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Abstract:

Agnihotra ash is the residue left behind after performing Agnihotra, a Vedic ceremony that involves burning cow dung and ghee at sunrise and sunset in a specially made copper pot. The ash has long been utilized in traditional Indian agriculture and is thought to possess a number of advantageous qualities. Agnihotra ash has garnered increasing interest recently as a sustainable agriculture ingredient. Based on research investigations and conventional wisdom, this review paper gives a general summary of the potential advantages of using Agnihotra ash in agriculture. The study emphasizes how Agnihotra ash enhances soil fertility, manages pests and diseases, fosters plant growth and controls soil pH. The study also explores the difficulties and possibilities of different application of Agnihotra ash on agricultural and environment factors.

Keywords: Agnihotra ash, physiochemical properties, water purification, air pollution,

Introduction:

Agnihotra is derived from two Sanskrit words 'Agni' means fire, and 'Hotra' means offerings. It is a Vedic fire ritual that has its origins in ancient Indian scriptures known as the Vedas. It is considered to be one of the most important yajnas (sacrificial offerings) in Vedic literature. This practice involves a particular offering time (sunrise or sunset) of incorporating cow's ghee and grains to fire while reciting mantras. Homa farming is based on the ancient Vedic science of Agnihotra, a healing fire practice based on the biorhythms of dawn and sunset. The approach of agnihotra is believed to impart spiritual and environmental benefits onto the farm crops. Moreover, it establishes a synergistic relationship between cosmic forces and individual and therefore, leads to potential health and ecological benefits in the environment. Agnihotra has a great significance in Hindu's belief and Vedic context, however, its practice and interpretation differs among different communities and individuals. Present population is forecasted to outreach 9.6 billion by 2050, however, the present agricultural production levels would need to increase by 70 per cent in order to feed such outnumbered population (Shubham *et al.*, 2022).

Indulging homa farming into the organic farming under guiding principle 'You take care of the atmosphere and in return atmosphere will take your care" is known as homa organic farming. Homa, the Sanskrit equivalent of yajna, is a Vedic science that uses healing fire to purify the air and repair the harmful contaminants from atmosphere. The major difference among Homa organic farming and other organic farming approaches is that Homa farming considers the environment to be the most significant and potential source of nutrition, whereas in other farming methods disregard the atmosphere as their primary element. Farmer's pressure on agricultural lands through cultivation of improved cultivars with inadequate organic and inorganic fertilizer application, improper crop residue management in soil have lead to nutrient pool depletion of macro as well as micronutrients (Shubham *et al.*, 2023).

In Agnihotra, dried cow dung, ghee (clarified butter) and brown rice are burned in an inverted, pyramid-shaped copper vessel while reciting special mantra (word-tone combination) with the biorhythm of sunrise and sunset. This process creates powerful purifying and harmonizing energies which is useful for heal atmospheric healing. The healing properties of Agnihotra preserved in the resulting ash are not only beneficial to plants but also to animals and people. Many medicinal qualities of Agnihotra can rejuvenate soil, plants, and people. Agnihotra is a super science from ancient wisdom given in these times as an antidote to pollution (Anonymous, 2023). The ancient Vedic disciplines of bio-energy, medicine, agriculture and climate engineering have given humanity a gift in the form of agnihotra (Figure 1). It is a straightforward approach which heals entire surroundings including farmland, crops and also improves individual's mental, emotional and physical health over entire world. Regular Agnihotra practice creates a biosphere which neutralizes the environmental pollution and generate serene atmosphere. Sitting in an Agnihotra environment is believed to relieve the stress in the body, mind and emotions in a gentle and effortless way. It involves burning dried Indian cow excrement that has been mixed with desi cow ghee in a copper pyramid cup that is the right size.

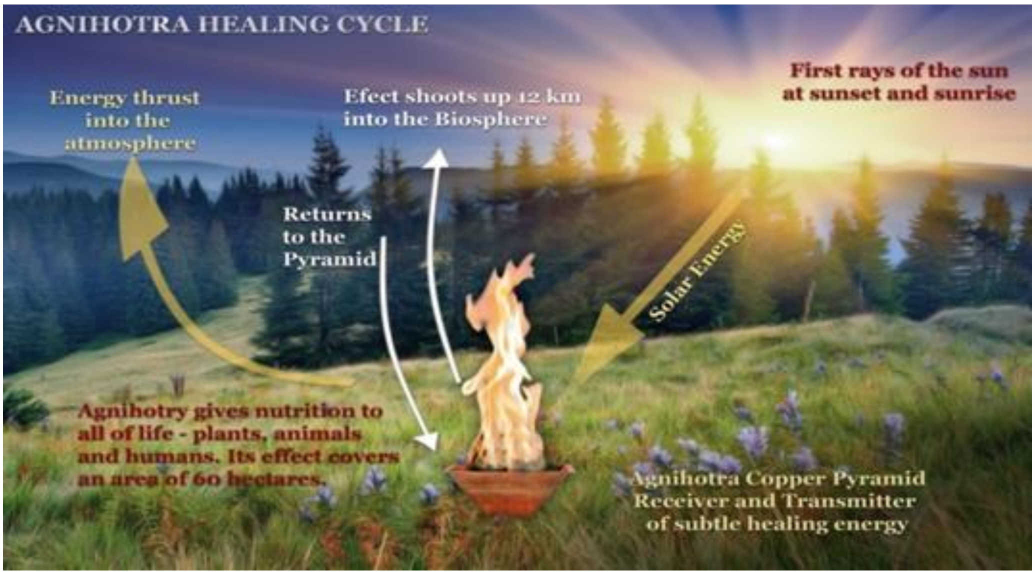

Figure 1: Process of Agnihotra

Characteristic components of Agnihotra

Figure 2: Ingredients of Agnihotra

A. Copper pot

A semi-pyramid-shaped pot made up of pure copper metal is recommended for Agnihotra. It is well known that copper imparts oligo-dynamic (*i.e.,* antibacterial) properties. Due to Agnihotra's close ties to fire, heat, electromagnetic forces and cosmic energy fields, copper plays a vital role in the process. Agnihotra pot shape complements the pyramid (Fire in the midst is the meaning of the word pyramid) (Figure 2). Egyptians in ancient times used the word 'Khuti' or "Khufu" which means beautiful light to describe the pyramids. The copper pot is fashioned like a pyramid, and therefore, it attracts, produces and distributes a unique healing and cleansing energy in the environment. It is observed that Agnihotra's potency is highest during sunrise and sunset period and thus needs to be done accordingly (Anonymous, 2022; Shubham *et al.,* 2021).

B. Cow dung

Certain species of bacteria (bacteriophages) are present in appreciable amounts in cow dung and therefore act as a powerful disinfectant.

C. Cow ghee

An offering of cow ghee made to the yagnya fire purifies the atmosphere and also provides a fragrant feel. The negative effects of all chemical based hazardous compounds that are dispersed in the environment as a result of severe pollution are neutralized when yagnya is done with offerings of pure ghee from Indian cows. Burning pure cow ghee releases gases that contribute to maintaining the equilibrium of natural cycle. The Ancient Vedas claimed that 'Cow's Ghee is Life'. Due to its immense medicinal potential, ancient healers (medical professionals) honored it by referring to it as medicine. Cow's ghee is combined with unbroken rice and Agnihotra oblations are offered to the fire while chanting the mantras. Cow's ghee produces acetylene, the energy of high heat which absorbs the impure air and purifies it after the oblations are offered to the fire. The gases that are created when cow ghee is burned have the great ability to relieve mental stress and to treat a wide range of illnesses (Anonymous, 2022

D. Unbroken raw rice

Rice has a yin-yang balancing effect. When it burns a lot of ethereal oils are produced and thus chemical processes starts off.

Agnihotra ash: A source of essential nutrients

Agnihotra ash provides macronutrients or micronutrients in appreciable amounts, and therefore, is regarded as crucial for plant growth and maintenance of soil health. It comprises of potassium (K), calcium (Ca), aluminium (Al), iron (Fe) and magnesium (Mg) in readily soluble forms. Incorporation of Agnihotra ash in soil raises the soil soluble phosphate concentration. Agnihotra mantra and sunrise/sunset times have a significant impact on Agnihotra ash. Usage of Agnihotra ash produced by chanting mantras at the appropriate times results in a higher phosphate content than control (*i.e.,* ash produced without mantra and not at the appropriate times) which directly influenced plant growth. Agnihotra improves soil fertility or nutritional value by reducing the microbial burden. Agnihotra ash is added to the soil increases the number of microorganisms that fix nitrogen and dissolve phosphate. Ash also destroys the fungi-causing germs at the same time. This will have a direct impact on the productivity and yield of the crops being grown in the field (Abhang *et al.*, 2015; Berk, 2016; Shubham *et al.*, 2021)

Physico-chemical properties of Agnihotra ash

In order to quantify the effect of Agnihotra on various biotic processes, it becomes important and crucial to precisely examine them. In order to comprehend how the energy changes during Agnihotra, it is important to quantify the life energy that certain substances and living things may receive or emits. Agnihotra involves an increase in life energy. Mantra chanting has a significant impact on the rise in life energy which plants may need for growth and typical physiological function. Majority of the cosmic energies employed in Yajnya are stored in ephedra or somavalli, which is specifically used in Somyag.

Agnihotra's burning fuel has a very low calorific value. Moreover, when base fire burns at a low temperature production of nitrogen oxide (NO) occurs. The copper pot's pyramidal design ensures that there is enough oxygen present for proper burning. When the Agnihotra fire burns, carbon dioxide and other environmentally safe volatile organic compounds are released. On the other hand, one of the greenhouse gases is carbon dioxide also evolve. Agnihotra is performed during sunrise and sunset, so the carbon dioxide that is produced can be used by the nearby plants to produce molecular oxygen. Base fire weakens molecules molecular bonds, causing substances to evaporate rather than undergo their own independent combustion. Acetone bodies, aldehydes and other chemicals are released after the quick burning of cellulose by fatty substances (mostly ghee). Yajnya purifies the surroundings by displacing the unpleasant odours with a variety of volatile organic molecules (Chandra, 2004). During the Yajnya process, hydrogen sulphide (H_2S) and nitric oxide (NO) which operate as bio-signalers and are involved in the growth of new blood vessels, regulation of Alzheimer's disease, etc., are released due to cow dung and ghee (a hump- backed Indian cow). All fat-soluble vitamins, including A, D, E, and K, are present in cow ghee. It has anti-aging properties and contains antioxidants which boost immunity, secrete biliary lipids, and regulate cholesterol levels. During the Yajnya procedure, a copper pot pyramidal shape is crucial for creating, storing, and transforming energy. Copper has antibacterial qualities and is a good energy conductor (oligo-dynamic action). The continuity of the earth's seasonal cycles is a result of yajnyas. Yajnya causes the surrounding environment to become denser, humid, heavy, fluid, etc., which causes clouds to form. Yajnya burning produces CO_2 which is crucial for the environmental carbon and oxygen cycles. By minimizing or managing the pollutants in the soil, air, and water, yajnya purify the environment Agnihotra ash is significantly affected by the use of cow dung, cow ghee, brown rice, copper pots, activity schedules, and mantra chanting all at once. Using the right Yajnya materials for performing Agnihotra reveals the presence of organic carbon and release of sulphate, phosphorus, potassium, iron, calcium, magnesium, manganese, aluminium, copper, and zinc. Agnihotra ash is believed to have a significant effect on several physico-chemical properties that make it useful for various applications. Some of the physiochemical properties of Agnihotra ash are as follows:

A. **pH value**: The pH value of Agnihotra ash ranges from 10 to 12, indicating that it is alkaline in nature (Inamdar and Karadge, 2016).
B. **Nutrient composition**: Agnihotra ash contains various essential nutrients (potassium (K), calcium (Ca), aluminium (Al), iron (Fe) and magnesium (Mg) which are essential for plant growth (Amte, 2017)
C. **Organic matter:** Agnihotra ash contains organic matter been shown to have antimicrobial properties and thus can be useful for treating various infections (Naik and Kulkarni, 2017).
D. **Heavy metal content**: Agnihotra ash has been found to be low in heavy metal content and therefore can be considered safe for use in various applications (Chandrakar and Dubey, 2017).

Impact of Agnihotra ash on soil fertility and crop productivity

Agnihotra ash application to soil is observed to have a positive effect on soil fertility and crop output. In a study by Sharma and Singh, 2018 they have studied the antibacterial effectiveness of Agnihotra ash in relation to several bacterial and fungi strains. The results indicated that as a natural alternative to synthetic pesticides, Agnihotra ash has found to have a strong antibacterial action. Abhang and Pathade, 2015 studied the impact of Agnihotra ash on plant growth and yield of tomato plants, results showed that treatment of Agnihotra ash considerably increased the plant growth and yield. Similar findings were reported by Singh and Singh, 2019, where the Agnihotra ash improved the soil pH. The outcomes demonstrated that adding Agnihotra ash greatly raised the pH of the soil and enhanced the soil's capacity to sustain plant development. In a field study, Singh and Singh, 2016 also reported that adding Agnihotra ash considerably improved the nutritional quality of rice as well as nutrient uptake. Agnihotra ash was found to fasten the rate of growth in rice crop and also the root and shoot length was significantly improved (Yadav and Singh, 2018). Agnihotra's effectiveness in speeding rice seed germination is not reliant on seasonal variations and therefore it works in all four seasons—summer, winter, fall, and harsh circumstances (Devi *et al.*, 2004). Farmers use their traditional understanding of Agnihotra or homa farming to forecast weather conditions, crop behavior, seasons, and other variables. It demonstrates the intricate relationships between farmers and the environment. The agricultural, environmental, animal, farming communities are the important aspects of Agnihotra technology (Sofia *et al.*, 2006)

Agnihotra for water purification

Agnihotra ash has been traditionally used in India for water purification and there are enormous scientific evidences to support its effectiveness in removing certain contaminants from water. However, more research is needed to confirm these findings and to understand the mechanisms behind such effects. Agnihotra ash has been shown to have antimicrobial properties and has been traditionally used to treat waterborne diseases such as cholera, typhoid, and dysentery (Sharma and Saini, 2018). A study conducted in India found that adding Agnihotra ash to water led to a significant reduction in bacterial and viral counts (Sivarajan *et al.,* 2013). Agnihotra ash has been shown to have adsorption properties and has been used traditionally to remove heavy metals such as lead, cadmium, and mercury from water. In another study, application of Agnihotra ash was found to be effective in removing the lead from contaminated water (Sangameswaran *et al.*, 2012). Agnihotra ash has been used traditionally to adjust the pH of water, particularly in areas where the water is naturally acidic. Agnihotra ash was effective in increasing the pH of acidic water (Adhikary, 2011).While these studies suggest potential applications of Agnihotra ash in water purification, it's important to note that the effectiveness of Agnihotra ash may vary depending on the type and concentration of contaminants present in the water.

Agnihotra for air pollution control

Agnihotra's fumes have therapeutic purposes and reduce air pollution. By eradicating or slowing the growth of germs, an agnihotra fume exhibits antibacterial capabilities, reducing the microbial burden in the immediate surroundings (Kumari *et al.*, 2015). Basic levels of SO_x and NO_x in the environment are controlled by the fumes from AgnihotraYajnyas, which are necessary for a pleasant and healthy environment for people, plants and other animals. During Yajnya, the amount of SO_x in the air can be decreased and the effects linger for a long time. The usage of cow dung during Yajnya, which serves as a nitrogen supply may be to blame for the NOx in ambient air increasing below threshold levels (Abhang and Pathade, 2015). Agnihotra ash has been applied in a number of ways to reduce air pollution. It has been discovered that the ash has a high capacity for adsorption which can assist remove pollutants from the air. Agnihotra ash also has alkaline qualities that can aid in neutralizing acidic air pollutants. Here are a few ways that Agnihotra ash is used to reduce air pollution: Agnihotra ash has been employed as an air purifier to combat indoor air pollution. Allergens, dust, and other airborne particles can all be removed from the air by burning the ash in a small container and releasing the resulting smoke (Naik and Kulkarni, 2017). Agnihotra ash has been utilised as an additive to cut down on vehicle exhaust pollution. The ash can aid in lowering harmful pollutants and particulate matter emissions when added to diesel fuel. Agnihotra ash has been utilised to reduce industrial emissions' impact on air pollution. The ash can be used to neutralise acidic pollutants such as sulphur dioxide and nitrogen oxides released by industrial processes (Upadhyay and Singh, 2015). Agnihotra ash has been utilized to lessen air pollution caused by agricultural activity (Singh and Gupta, 2018). By using the ash as a natural fertiliser, we can lessen the need for chemical fertilisers that can pollute the air (Amte, 2017). In general, the utilisation of Agnihotra ash for air pollution control is a promising field of study that can provide a long-term solution to the issue of air pollution.

Agnihotra for different disease and disorders management

Agnihotra ash has been traditionally used topically to treat wounds and promote healing. A study conducted on rats found that topical application of Agnihotra ash led to faster wound healing compared to control group rats (Kulkarni *et al.*, 2015). Agnihotra ash has been used traditionally to treat skin diseases such as eczema, psoriasis, and acne. A small study conducted on patients with psoriasis found that a cream containing Agnihotra ash led to a significant improvement in symptoms (Shukla *et al.*, 2011; Ashlesha and Paul, 2014: Sharma *et al.*, 2014). Agnihotra ash has been used traditionally to treat respiratory disorders such as asthma and bronchitis. A study conducted on guinea pigs found that inhalation of Agnihotra ash led to a significant improvement in respiratory function (Vaidya *et al.*, 2006). Agnihotra ash has been traditionally used to treat digestive disorders such as constipation and gastritis. A small study conducted on patients with chronic constipation found that ingestion of Agnihotra ash led to a significant improvement in bowel movements (Tripathi *et al.*, 2016). It's important to note that while these studies suggest potential medicinal benefits of Agnihotra ash, more research is needed to confirm these findings and to understand the mechanisms behind these effects.

Agnihotra ash for radioactivity source

Due to the high quantities of natural radioactivity that have been discovered in Agnihotra ash, it can be helpful in minimizing the negative effects of exposure to external radiation. According to studies, the high amounts of naturally occurring radioactivity in Agnihotra ash can assist to attenuate and neutralize the damaging effects of external radiation by absorbing it (Inamdar and Karadge, 2016; Khurana *et al.*, 2016). In one study, mice exposed to gamma radiation were treated with Agnihotra ash to lessen the adverse effects of radiation. The study's findings demonstrated that Agnihotra ash was efficient in lowering levels of free radicals and lipid peroxidation which are the primary causes of radiation's adverse side effects. Agnihotra ash was discovered to be useful in lowering radiation exposure in workers who were exposed to ionising radiation while at work in another investigation. The study's findings demonstrated that using Agnihotra ash significantly reduced the workers radiation exposure levels (Srinivasan *et al.*, 2011*)*. Overall, research on using Agnihotra ash to lessen the negative effects of radioactivity is still in its early stages, and further study is required to fully understand Agnihotra ash potential in this regard.

Conclusion:

Despite the fact that Agnihotra is an ancient ritual, it is today utilized as a cure in many nations to heal various plant or animal ailments, to manage pollution brought on by human interferences, to raise agricultural productivity. Agnihotra ash has been discovered to have advantageous impacts on soil health and plant growth including enhanced soil structure, increased nutrient availability and higher crop yields. It has been demonstrated that using agnihotra ash in agriculture can effectively lessen the detrimental effects of chemical pesticides and fertilizers on soil health and plant growth. Moreover, it has been shown that Agnihotra ash has anti-fungal and anti-bacterial characteristics that could help shield plants from illnesses. However, elements like soil type, climate and the crop being grown can affect the effectiveness of Agnihotra. Consequently, more research is required to establish the ideal treatment rates and techniques for various crops and growth environments. Agnihotra technique has numerous uses in a variety of fields including technology, industry, medicine, agriculture, bio-remediation and pollution management. Agnihotra technology preserves balance between nature and living things since it is environmentally beneficial. One must properly utilize Agnihotra, its gases and its ash in order to solve today's problems. When attempting to adopt Agnihotra technology as a remedy for everyday issues one must take into account both its potential good and negative effects.

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AN ADVANCED TECHNIQUES IN PEST MANAGEMENT

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Abstract:

Agriculture plays an integral role in feeding the world's growing population. At the same time, its production declined due to certain factors, such as biotic and abiotic factors. The insect species which causes economic damage is called Pest, which causes a loss of about 10 %. Conventional pest management has certain limitations, such as harmful to natural enemies and beneficial organisms, environmental pollution and increased cost of cultivation. 80% of farmlands in India are under small and marginal land having an area of less than 1 hectare; hence management practices in one field may cause shifting of pests to neighbouring fields, which reduces the efficiency of the practice. Therefore, a community-based approach is to be taken for effective management tactics. This leads to switching to advanced strategies in pest management. One such approach is based on remote sensing; it helps to detect the insect pest incidence area by using the principle of reflectance and the use of drones to perform various actions such as the application of insecticides, release of natural enemies, sterile insects and capturing of aerial images. The advantages of genetic engineering technology also utilize for developing certain genetically modified crops with various traits, such as against insect and insecticide resistance. A biologically based technique called the sterile insect technique helps to reduce the pest population by inhibiting the reproduction capacity instead of killing the Pest and also without harm on other species. These emerging advanced techniques give more sustainable and environment-friendly management tactics and also reducing the pesticide residue in agricultural commodities thereby it improves its value addition and enhance secondary agriculture.

Keywords: Drone, Genetic engineering, Pesticide residue, Remote sensing, Sterile insect technique, Sustainable agriculture.

Introduction:

Agriculture plays an integral role in feeding the world's growing population. At the same time, its production declined due to certain factors, such as biotic and abiotic factors. Among biotic factors, Pest causes a loss of about 10 %. World pesticide consumption is growing at 5% per year and, at the same time, has certain limitations, such as harmful to natural enemies and beneficial organisms, environmental pollution, and increased cost of cultivation. Because of the above, there is an urgent need to develop and implement more environment-friendly methods to manage insect pests, such as the Sterile Insect Technique (SIT), that are biologically based and, therefore, more sustainable. It helps to reduce the pest population by inhibiting the reproduction capacity instead of killing the Pest without harming other species. The second approach is Remote sensing technology, which is reliable and provides accurate information to guide decision-making in crop pest management. The narrow bands in the hyperspectral remote sensing can measure plant pigments' characteristic absorption peaks more precisely, thereby providing better information related to plant health. Sensing and actuation drones could contribute to the prevention of pest outbreaks. A forecasting system for insect pests in Agroecosystems provides an opportunity to inform farmers about possible outbreaks for preparedness and take timely action to apply biocontrol agents, mechanical means, and pesticides, which ultimately cuts down the cost of production. Another technique is Genetically engineering, which develops genetically engineered (GE) crops that protect against insects and diseases or tolerance to herbicides/pesticides.

An expansive range of conventional insecticides, such as carbamates, organophosphates, pyrethroids, and organochlorines, have been used to control insect pests in recent decades, reducing the loss of agricultural yield. Still, at the same time, it reduces the product's quality as it contains high pesticide residue. So, it is necessary to apply novel technologies such as remote sensing, genetic engineering, and sterile insect techniques for pest management that produce high-quality food, enhancing primary produce value addition and processing and leading to better income generation.

This chapter details the abovementioned techniques and their application for insect pest control.

Remote sensing

Remote sensing is the non-contact measurement of radiation emitted or reflected from agricultural fields. It is based on the relationship between electromagnetic radiation and soil or plant matter. Early warning and forecasting using biophysical methods can help farmers promptly manage pest damage, reduce crop loss, optimize pest control, and reduce cultivation costs. Remote sensing can collect data from various sensors, such as EMR, aerial photos, and satellites. These sensors can be remotely collected and analysed to get information about an object or phenomenon being sensed. It can also acquire information about the Earth’s surface by measuring the radiated energy produced by aircraft- or spacecraft-borne sensor systems. Many of the research and management uses of remote sensing can be tactical, meaning they can be used to respond to specific conditions or events that occur during the season, for example, to control insect pest populations. The tactical questions often include determining how fields are changing, for example, detecting the emergence of a new pest population. To do this, you must collect and compare images to previous images frequently.

Application of remote sensing

- Environmental conditions and forecasting of locusts

- Crop pests assessment
- Early identification of wild hosts and reduction of population build-up
- Early identification of insect pests
- Identification of pest infestation hot spots in crops
- Pest control monitoring conditions favourable for pest emergence
- Remote sensing of specific insects
- Surveying of insect pests in crops and fruit trees
- Geographic distribution of pests combined with Geographic Information System (GIS)
- Rainfall and prediction of pest outbreak

Drones

Traditional pesticide and fertilizer spraying methods are time-consuming and ineffective, necessitating technological advancement. In such circumstances, it is essential to have the ability to spray plant protection measures promptly. The unmanned aerial vehicle (UAV) offers a range of advantages, such as increased efficiency, decreased labour, extensive area coverage, time and response time savings, and environmental safety. Drones are also becoming increasingly popular as an insect pest control method in the agricultural sector. Agricultural drones are semi-automated devices that are gradually transitioning to fully automated ones. These devices offer a great deal of potential in terms of agricultural planning and the collection of spatial information.

Applications in Insect Pest Management

1. Drone mediated remote sensing:

Remote-sensing drones will likely cover a much larger area than handheld, land-based devices. Insect pest infestations can cause physiological responses in plants, resulting in alterations in their photosynthesis capacity and changes in the spectral range of leaf reflectance. Drones can be equipped with RGB sensors (red, green, blue), multispectral sensors with a range of spectral bands from 3 to 12, or hyper-spectral sensors with hundreds of spectral bands to facilitate remote sensing (Iost Filho *et al*.,2020). It is important to note that remote sensing does not detect pests but rather patterns of reflectance from the canopy that are indicative of plant stress caused by insect pests. Therefore, field observations are still necessary to determine the presence of a particular insect pest.

2. Drone mediated aerial photography

Drones have revolutionized plant pest surveillance through aerial photography, wireless sensor clusters and networks, and precise agricultural design. Drones can give farmers a 360-degree view of their fields and enable them to make critical management decisions within problem-solving time. The drone images are sent to a cloud data center to analyze the level of damage caused by pests using spectrum analysis technology (Gao *et al*., 2020).

3. Drone mediated insect pest sampling

A drone-attachable device is available to capture airborne insects as a position-fixed or freely movable trap. If the apparatus is sufficiently well developed and used for insect pest sampling, a DD-screen (Double-charged Dipolar Electric Field Screen) can be attached to the drone. This screen creates an electric field between the traps, creating an attractive force to attract insects that enter the field. The field is strong enough to prevent the insects from escaping the trap (Takikawa *et al*., 2020).

4. Drone mediated precision application of insecticides

The actuation drone has the potential to assist in controlling pests in infested areas of the agricultural field by varying the insecticide application rate. New types of drones, equipped with crop dusting and spraying equipment, are being developed in various parts of the world as commercial drones. In addition to precision monitoring, applying pesticides with precision could reduce the overall number of sprays, thus contributing to a decrease in the use of pesticides, a decrease in the development of insect resistance, and an increase in the presence of natural adversaries in the field.

5. Drone mediated precision releases of natural enemies

Unmanned aerial vehicles (drones) are a viable option for augmentative bio-control, which relies on the widespread dispersal of natural enemies to facilitate the immediate eradication of harmful organisms. Drones could distribute these natural enemies precisely in the desired areas, increasing the effectiveness of biological control agents and decreasing the distribution cost.

6. Drone mediated Sterile Insect Technique (SIT) and mating disruption

The release of sterile insects may also be a potential application of drone technology in pest management. Studies have been conducted to control sterile insect populations through drones in various countries, including Canada, New Zealand, and the United States. Additionally, research has been conducted in the citrus field to control cotton pink bollworms and Mexican fruit flies, successfully controlled with drone-release sterile insects in the United States.

Advantages of drones (Pushpalatha *et al*., 2020)

- High payload capacity
- Higher flight time
- Higher speed
- Strong and durable
- Access to remote areas
- Petrol or gasoline-powered UAV (unmanned aerial vehicle)
- Ability to land vertically
- Forward, backward movement

- Less time consuming
- Low labour requirement

Disadvantage of drones

- High costs
- Requires skilled labours for operation
- Complexity in collection of data, its analysis and interpretation
- Can’t be used during adverse climatic conditions
- Applicable only for large scale spray

The Sterile Insect Technique (SIT)

The sterile insect technique (SIT) is simple and based on the principle of releasing many reproductively sterile male insects into a wild population of the same species so that they mate with and block the reproduction of wild females (Knipling, 1955). This program includes mass production of the desired insect pests, sterilization, and release into the field regularly and in enough numbers to attain an appropriate amount of flooding (sterile: wild insect ratio).

1. The conditions necessary for the successful implementation of SIT include:

- The presence of a low-level target pest,
- A comprehensive understanding of its biology and ecology,
- The ability to raise the target pest in large numbers,
- The ability to release and monitor the sterile individuals effectively,
- The need for the releases to be applied across an entire area and not be used by a single farmer.

2. In situations where the SIT could be considered for control:

- The emergence of an infestation of non-native pests that could have a significant effect on agricultural or ecological systems
- The vector of severe disease (plant, animal)
- The presence of a "key pest" that significantly increases management costs and the quarantine of a pest in a potential export market
- The disruption of ecological processes that control populations of other pest species by alternative methods of pest control
- The prevention of pest establishment by maintaining a continuous insect population in an area with a high risk of infestation (Lance *et al*.,2021).

3. Biological characteristics that enhance the feasibility of the use of the SIT include

- The ability to reproduce sexually (exclusively)
- The availability of mass-producing methods
- The holometabolous species (the quiet pupal stage makes it easier to sterilize and handle)
- The ability of male animals to compete for mates with wild males

- The ability to monitor both released sterile populations and wild populations
- A low intrinsic rate of growth.

4. Biological characteristics that may severely complicate the use of the SIT:

- Parthenogenesis
- The mating system is highly synchronous, aggregated and ephemeral (e.g., Eusocial insects and Ephemeropteran insects.)
- Extended life cycle e.g., cicadas
- Sterile insect species that are also serious pests, disease vectors, or nuisance pests (e.g., horn fly, locust, house fly, cockroach, female mosquito, Etc.
- Migration behaviour that involves long-range flight and movement along the weather fronts, such as in many moths (eusocial insects), locusts (plural planthoppers), and stable flies.

5. Strategic approaches of SIT

There are mainly four strategies followed such as eradication, suppression, containment and prevention (Vreysen *et al*., 2006). Each approaches describing below;

5.1. Eradication

The melon fly has caused considerable damage to various hosts in the Okinawa Islands, leading the Japanese government and local prefectures to launch a campaign to eradicate it from the southwestern islands. After a pilot program was conducted on Kume Island to demonstrate the feasibility of the proposed strategy, a full-scale campaign was launched in 1984 with the addition of an SIT component. Initially, a facility was set up to produce sterile melon flies with an initial capacity of 30 million male flies per week. However, this capacity increased to 200 million males per week by 1986. The population of the fly was reduced to a mere 5% of its initial level through the male annihilation technique, and the sterile males were then dispersed by helicopter (Koyoma *et al*., 2004). By 1993, the fly had been eliminated from the Okinawa Islands.

5.2. Suppression

AW-IPM has been proven to successfully suppress a significant lepidopteran pest, such as codling moth, in the British Columbia region of Canada. This pest is the most prominent of the pears and apple pests in the province. Several technological advances have enabled the rearing of Mediterranean fruit flies to be more efficient, decreasing the cost of the Single Insect Test (SIT) component and making it more cost-effective than other more conventional control strategies. As a result, most AW-IMM programs with SIT components against codling moth are currently focused on suppression rather than eradication.

5.3. Containment

Agreements were signed in 1976 and 1977 between the governments of Guatemala and Mexico, as well as the United States of America, leading to the creation of the "Programa

Moscamado". This program aimed to control the Mediterranean Fruit Fly in Guatemala and stop it from spreading to Mexico and the US, using a combination of AWIPM and SIT components to protect the horticultural industry in the three countries.

5.4. Prevention

Until 1980, California and Florida experienced regular Mediterranean fruit fly infestations, which were largely eradicated through aerosol sprays, often sprayed over urban areas. In 1996, a comprehensive preventive release program was implemented in the Los Angeles Basin, which has since released over 400 million sterile males over a vast area of 2.489 square miles each week.

Application of SIT

The first SIT program was widely recognized for successfully eradicating the New World Screw Worm (NWS) in 1954, which has since been eradicated from large parts of Central and North America. The screwworm (*Cochliomyia hominivorax*) is a fly that causes myiasis and is a major economic burden in agricultural systems with large livestock production or face increased labor costs.

The Mediterranean fruit fly, Ceratitis capitata, is a well-known quarantine pest due to its wide range of host attacks. This species has been a major target of the SIT program, with the first large-scale SIT program against this species being launched in Mexico in 1977. This program involved the construction of a 500-million-seated facility for fly mass rearing.

On the other hand, the Tsetse Fly has a devastating impact on human health and livestock production in the 38 southern countries of the Sahara region, covering an area of between 7 and 11 million km^2. It is a major obstacle to the development of sustainable agriculture in many areas with high agricultural potential due to the resistance they cause to trypanosomiasis.

Moths are one of the most destructive pests to food, fibre, and forest crops, as well as to stored resources, all over the world. In California, a program has been successfully implemented since 1968 to control the pest known as codling moth. This pest is a major problem for apple and pear growers in temperate regions and is often sprayed with powerful insecticides. The SIT program was launched in British Columbia in the early 90s to combat the problem with the help of federal and provincial government funding to construct a large-scale breeding facility that can produce 15 million larvae per week. Four years into the program, most growers have reported no damage and can produce organic fruit without spray (Hendrichs *et.al*.,2000).

Advantages of SIT

- This method of biological control is not disruptive to the natural environment
- Does not cause harm to non-targeted organisms
- Density-dependent
- Can be easily incorporated with other forms of biological control, including parasites, predators, and pathogens.

Disadvantages of SIT

- It is sometimes necessary to suppress populations by naturally low population periods or repeated pesticide treatment before using sterile insects.
- Sex separation can be challenging, but it can be easily done on a large scale where the genetic sexing system has been developed, as in the case of the Mediterranean Fruit fly.
- Radiation, transport, and release treatments reduce the mating fitness of the males.
- The technique is specific to the species
- Mass rearing, irradiation, and release procedures require precision.
- An area-wide approach can be more effective since wild insects may migrate from outside the control area and cause the problem to be repeated.
- Producing enough sterile insects in some locations can be expensive, but it decreases as economies of scale are achieved.

Genetic engineering

Genetic engineering (GE) is a fundamental component of Integrated Pest Management (IPM) and can complement other pest management strategies. Most GE crops offer tolerance to herbicides such as Glycerin, Glufosinate-amide, Dicamba, and 2-4 D, as well as protection against Lepidopteran, Coleopteran, and other pests. Insect protection has been developed through Bt-derived insecticidal proteins, which can be found in cotton, soybeans, and corn varieties. Additionally, GE crops have evolved from insect protection traits derived from Bt to RNAi-based or non-Bt-derived proteins. Numerous benefits are associated with using GE crops in insect control, such as reduced use of less effective or less eco-friendly insecticides, increased pest specificity, and a more user-friendly insect pest management strategy.

1. Insect resistance trait

Bacillus thuringenesis is a Gram-positive, soil-dwelling bacterium capable of producing insecticidal Cry toxins (Cry 1, Cry 2, Cry 3, Cry 4, etc.). These Cry toxins are not toxic to humans, other mammals, or non-target insects. As a result, Bt has been used as an alternative crop pest control agent to synthetic insecticides. Various highly pathogenic Bt strains have been identified with specific activity against various insect species. The endotoxins encoded by Bt have been classified based on amino-acid sequence-like classes (Cry 1, 2, 3, 4, etc.). These classes are subdivided into subclasses, including Cry1A, Cry1B, Cry1C, etc.), which are subdivided into subfamilies or variants (Cry1Aa, Cry1Ab, Cry1Ac, etc.). However, only some of these classes have been used in genetically modified crops for insect resistance. Some of the most common commercial ones are Cry3Bc1, Cry34A1/35A1, Cry1Ab, Cry1A, Cry1F, Cry3A, Cry3A (Western corn rootworm resistance), Cry1A (European corn borer resistance), Cry1F (Western bean cutworm resistance), Cry3A (Colorado potato beetle resistance), Cry1Ac / Cry2Ab (Cotton bollworms resistance) and budworms resistance (Jones,2016).

Vegetative Insecticidal Proteins (VIPs) are not part of the same family, but like Cry, they also have very strong and specific insecticidal activity. The protein Vip1 and the protein Vip2 are toxic to certain members of the order Coleoptera and some of the order Hemiptera. Vip3A is insecticidal against a broad spectrum of Lepidopteran insects. It has acute bioactivity against the black cutworm. Interestingly, the European corn borers (*Ostrinia nubilalis*) are not susceptible to the protein Vip3A. The insect host range of Vip3A is determined by its binding to insect gut cells. Commercial Bt cotton varieties and Bt maize varieties express Vip3A in combination with Cry protein.

2. Insecticide resistance use

The introduction of genetically modified insect-resistant crops has positively impacted agricultural yields and incomes, especially in developing countries. This is especially true for cotton, which has traditionally been subject to extensive insecticide use to combat bollworms and budworms. The widespread adoption of genetically modified cotton and the subsequent reduction in insecticide spraying has resulted in a significant increase in the presence of beneficial arthropods such as ladybirds, lacewing, and spiders, as well as a reduction in aphid infestations. The concept of a "refuge" is a key component of these Insect Resistance Management (IRM) programs, which involves the cultivation of plants (usually of the desired crop) that contain no Bt protein to facilitate the production of insects susceptible to Bt. An additional issue that Bt crops may face is the potential for a shift in the number of pests, such as an increase in the number of secondary pests collaterally or incidentally, controlled by a broad-spectrum insecticide but not a selective GE trait.

In China, the widespread use of genetically modified cotton (Bt) and the subsequent decrease in chemical insecticides has increased mirid beetle populations in certain fields. When a technology, including a genetically modified version (GE), is used to reduce or eliminate a primary pest significantly, it is possible that other environmental factors, such as replacement inputs, will lead to a shift in the pest population that may necessitate the use of additional crop protection (CP) inputs. If these additional inputs are chosen carefully, the overall benefits to growers remain high. At the same time, the advantages of adopting a GE trait may be significantly reduced due to the additional input costs and the potential loss of environmental and health benefits ((Jones,2016). While genetic engineering is not the only solution to all problems, it is not necessarily the only way to become a long-term IPM strategy, either through using GE technology or developing host plant resistance through conventional methods.

3. Potentials of biotechnology in Ipm

- The ability to express toxins in all parts of the plant,
- Eliminating the need for constant monitoring of pest populations
- Providing protection to parts of the plant that are difficult to treat with insecticides
- No drift issues, and no contamination of groundwater.

- It is safe for non-target animals and humans, eliminates the issue of shelf life
- Field stability
- Built-in resistance to a variety of insects.

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THE IMPACT OF GROWING FOOD ON CLIMATE AND THE POSSIBLE SOLUTIONS TO COMBAT AND REDEEM

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Abstract:

Climate change is a reality and we have started to feel it. The primary reason for climate change is the amount of greenhouse gases (GHG) being added into the atmosphere which has been estimated at 51 billion tons per year. This article talks about the role of agriculture in impacting the climate change as agriculture per se contributes 19 per cent of the total GHG emission. From the manufacturing of fertilizers to growing of crops and livestock, the practices we follow yields a lot of GHGs. Crop cultivation has resulted in the increment in the amounts of Carbon dioxide, Nitrous oxides and Methane which are powerful in harming the climate. For example, for 10 consecutive years, Carbon dioxide has increased by more than 2 parts per million, which represents the fastest sustained rate of increase in the 63 years since the monitoring began. Similar trend has been seen in case of Methane. Even the shift to organic farming is also argumentative as it can also lead to increase of GHGs. In the article, the authors have tried to highlight the issue and talked about the possible solutions to overcome the problem and redeem so as to sustain diligently in a safe environment and simultaneously ensuring food security for the globe. 40 percent of the carbon emissions is from top 16 percent population, so the rich nations should collaborate and spend more on research regarding reducing the ill effects of climate change. Inter-disciplinary research can prove itself to be very fruitful during these times. Techniques like Direct Air Capture, production of green Ammonia, developing feed additives like 3 NOP are some innovations which require more and more attention in order to reduce the emission of GHGs resulting from agriculture. Chemical toll of fertilizers and livestock needs to be managed through these breakthroughs.

Keywords: Greenhouse gases, climate change, Direct air capture, 3 NOP, agriculture

The conundrum of climate change and the role of farming in aggravating it:

Every year, we are adding 51 billion tons of greenhouse gases to the atmosphere (breakthroughenergy.org). Agriculture is one practice that yields in addition of greenhouse gases in the atmosphere. 19 per cent of the 51 billion tones is contributed by Agriculture (Gates, 2021). While growing the food, we are producing enormous amounts of greenhouse gases, mainly Carbon dioxide and Methane. We also make heavy use of fertilizers and chemicals, the making processes of which also add more greenhouse gases into the air. It is found that the soil management practices that release Nitrous Oxides (N_2O) are the largest sources of greenhouse gases consisting of 49 per cent of the total 19 per cent. The second largest source is the methane produced from Livestock and rice cultivation which makes up 42 percent of the total 19 percent (Gates, 2021). Our population has been expected to reach 9.8 billion by 2050 (FAO, 2017). India has become world's most populous country in the world with its population growth rate of 0.66 per cent and density of 431 persons per kilometer square (https://worldpopulationreview.com/). Well, the concern is not just about India, overall, the global population is increasing with some countries showing very positive growth rates of as high as 3-4 percent. These nations are mostly from the continents of Asia and Africa where majority of the destitute population of the world resides. And the repercussions are clear, with the increase in population, there is going to be a cut throat competition for resources especially the food resources. The nutritional security will be endangered. We will have to produce more and more food to meet the demands of ever-increasing population and all this is going to increase the share of agriculture on total GHG emissions. With growing more food, we will add more methane, more Carbon dioxide and more Nitrous oxides into the atmosphere. The amount of devastation that these gases cause is also different. For example, Methane is more potent of causing global warming than Carbon dioxide. While carbon dioxide is more abundant and longer-lived, methane is far more effective at trapping heat while it lasts. After its release, methane is more than 80 times more potent than carbon dioxide in terms of warming the climate system (Garthwaite, 2021). The situation is gruesome and it can be understood from the fact that even after complete or partial lockdowns during Covid-19 imposed by most of the countries, the carbon and methane levels have surged. According to a report by National Oceanic and Atmospheric Administration, the annual increase in atmospheric methane during 2021 was 17 parts per billion (ppb), the largest annual increase recorded since systematic measurements began in 1983. The increase during 2020 was 15.3 ppb. Atmospheric methane levels averaged 1,895.7 ppb during 2021, or around 162% greater than pre-industrial levels. From NOAA's observations, scientists estimate global methane emissions in 2021 are 15% higher than the 1984-2006 period (Fig. 1).

Similarly, the Carbon dioxide has shown a similar trend (Fig. 2). The global surface average for carbon dioxide during 2021 was 414.7 parts per million (ppm), which is an increase of 2.66 ppm over the 2020 average. This marks the 10th consecutive year that carbon dioxide increased by more than 2 parts per million, which represents the fastest sustained rate of increase in the 63 years since its monitoring began. The situation is alarming and we need to take immediate actions on this matter. There are some breakthroughs in place but we have to think of more and more in order to challenge this peril. Bill Gates, in his book *How to avoid a climate disaster* talks of the grimness of the situation and some breakthroughs that we have and those we still need. We need more powerful people throughout the globe to aggregate, think and act upon.

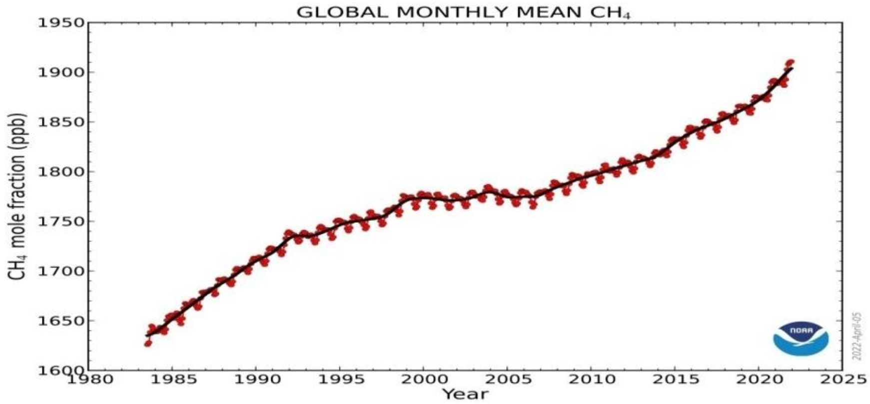

Figure 1: This graph shows globally-averaged, monthly mean atmospheric methane abundance determined from marine surface sites since 1983 (Source: noaa.gov.in)

In this article, the main focus is going to be on how growing crops affects climate negatively and what can be the possible strategies to adopt to combat these negative repercussions.

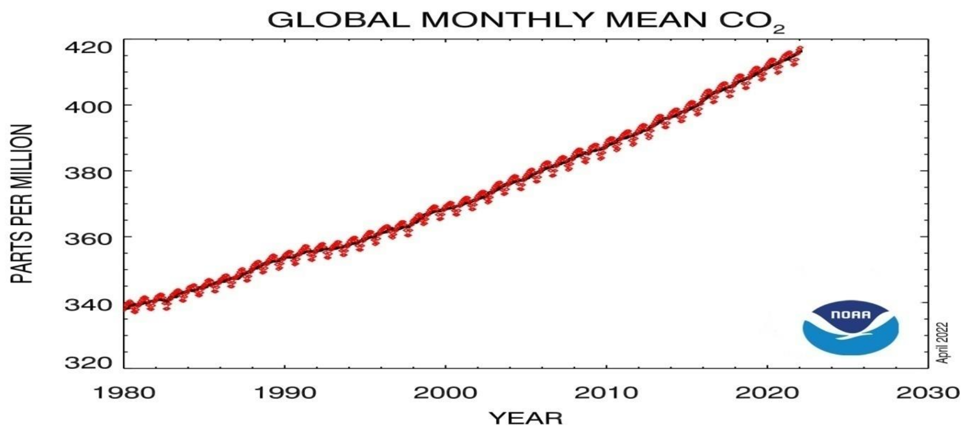

Figure 2: CO_2 trend: This graph shows the monthly mean abundance of carbon dioxide globally averaged over marine surface sites since 1980 (*Source: noaa.gov.in)*

The climate toll of fertilizers:

After Green revolution, Indian farmers started making exorbitant use of chemical fertilizers and pesticides in their fields to obtain miraculously higher yields. But the feritlizers have also paid their part in aggravating the GHG emissions. To make fertilizers, Ammonia is produced for which we burn the natural gas and fossil fuels to obtain heat for the reaction. The burning of natural gas produce greenhouse gases. Also, when fertilizer is added to soil, not all of it is absorbed by the crops. The residual slips off to the soil and reaches ground water, or escapes in the air in the form of Nitrous Oxides, which have even more warming effect than Carbon dioxide. The resiudes of fertilizers in the soil are broken down by soil microbes and are released in the atmosphere in the form of greenhouse gases. So it is clearly evident that the production as well as application of fertilizers both result in Greenhouse gases emissions. By the way, we are also aware of the ill effects of fertilizer usage on the biodiversity. The run off fertilizers when enter the water bodies result in the widespread fish kill. The excess of nutrients coming from the fertilizers causes eutrophication, increased plankton biomass and oxygen deficiencies in the bottom water of shallow areas and of basins. If we take an exomple of Baltic Sea (an arm of Atlantic ocean), Phytoplanktons and cyanobacteria have killed so many species of aqautic animals.

But researchers believe that we can reduce the GHG emission by producing green Ammonia by electrochemical reactions or electrolysis and not by burning fuels. Generally Hydrogen is taken from methane which is a dangerous Greenhouse gas. Instead of methane, we can shift to some other source of Hydrogen (to make ammonia) *eg*. water. The electrolysis of water can yield us Hyrogen but that is also a very dangerous process as Hydrogen is a highly combustible gas. So we will have to find out ways to reduce the risk of accidents and simultaneously increase the amount of Hydrogen that we will obtain from these carbon free processes. “There’s a whole kind of space race happening at the moment in the area of green ammonia,” says chemical engineer Patrick “PJ” Cullen at the University of Sydney, Australia (Ornes, 2021). The solution does not lie in renoouncing the use of Ammonia but rather producing carbon free or Green Ammonia. This can also be achieved by capturing and storing Carbon Dioxide which is released by the conventional Haber-Bosch process. This technique is called Carbon Sequestration. But this and some other similar processes like Point Capure and Direct Air Capture (DAC) are very much expensive. They can be made feasible only when huge private investment and government funded research will be there to encourage widespread production of such systems. It is believed that the cost of a technology decreases when it is made in use over and over again and on a large scale. So we require huge lot of support from Government, Elite class of the world and Investors to fund more and more in this field.

Another way to produce green ammonia, suggested by the scientists is the on-site production of fertilizers as and when needed using renewable energy on which we do not yet have a clear insight but such sort of projects are under consideration. This will reduce the financial and environmental expenditures of transporting and storing ammonia. We can also sidestep Haber-Bosch process through the electrochemical nitrogen reduction reaction, or ENRR, which fuses hydrogen from water and nitrogen gas from the air to produce ammonia. The ammonia yield from ENRR is lower than that of Haber-Bosch, but several studies published in the last two years suggest that new metal catalysts and approaches, based on renewable energy sources, could improve on current performance. (Ornes, 2021).

The chemical toll of livestock

The Global Livestock Environmental Assessement Model (GLEAM) developed by FAO in 2017 shows in Carbon dioxide equivalents, the greenhouse incidences that enteric fermentation and manure storage have across the main livestock species raised worldwide.

It can be seen from the Figure 3 that the beef and dairy cattle are responsible for generating maximum of Carbon dioxide equivalents i.e 1.8 and 1 Gigatonnes respectively. They release greenhousegases from their enteric metabolism as well as from the dung that is stored for later usage. In addition to greenhouse gases arising from enteric fermentation and manure storage, feed production together with the related soil carbon dioxide and nitrous oxide emissions is another important hot spot for the livestock sector. Soil carbon dioxide emissions are due to soil carbon dynamics (e.g., decomposing plant residues, mineralization of soil organic matter, land use change, etc.), the manufacturing of synthetic fertilizers and pesticides, and from fossil fuel use in on-farm agricultural operations (Goglio *et al.*, 2018).

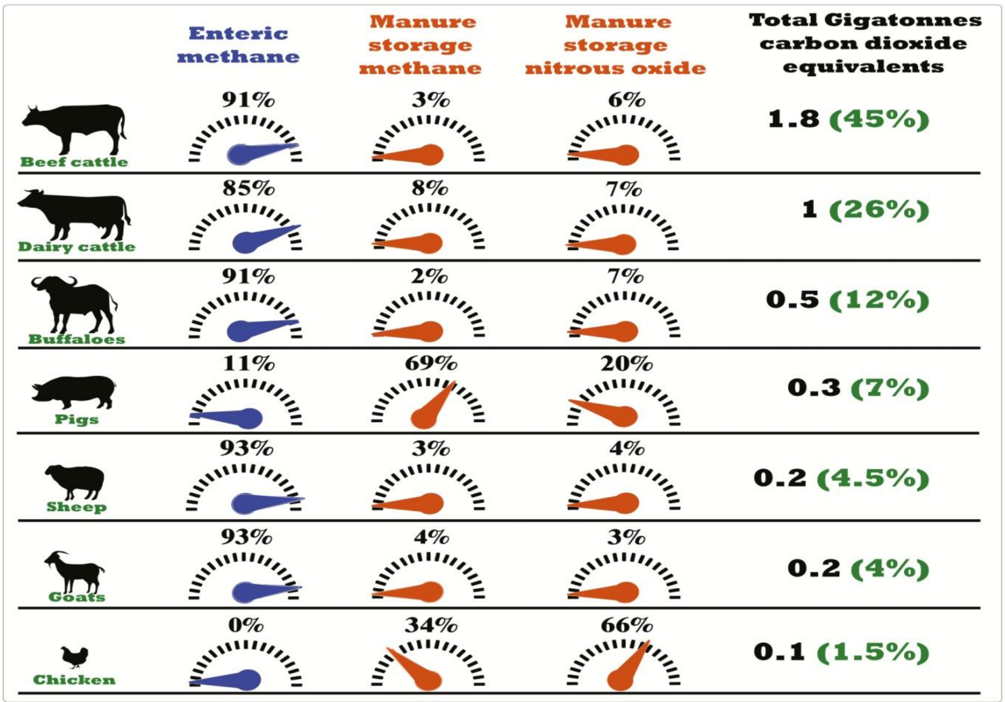

Figure 3: Greenhouse gases incidence of enteric fermentation and manure storage by animal type, expressed as Gigatonnes of carbon dioxide equivalents. Data referred to 2010 (FAO, 2017)

Feed production and processing contribute about 45% of the whole sector (3.2 Gigatonnes of carbon dioxide equivalents). Enteric fermentation producing about 2.8 Gigatonnes (39%) is the second largest source of emissions. Manure storage with 0.71 Gigatonnes accounts for about 10% of the total. The remaining 6% (0.42 Gigatonnes of carbon dioxide equivalents) is attributable to the processing and transportation of animal products (Gerber *et al.,* 2013). Feed production involves various tasks to be employed on the field. They are:

- Land use change which involves deforestation for preparing fields
- Production and application of fertilizers
- Livestock excreta and its storage and application to the fields
- Agricultural operations, feed processing and transport

This problem has to have a solution. We need to be adamant about developing certain mitigation strategies to overcome this problem. Hristove *et al.* (2013) (Hristov *et al.*, 2013) talk about the consideration of 'Pollution swapping effect' while devising any mitigation strategies. This means that while developing one strategy, we should not let the other alternative to cause more devastation. For instance, as we are shifting to organic farming in order to reduce the use of chemical fertilizer, but it might aggravate the climate change problem because we will be using more and more of manure. Another example can be taken that reduction of direct nitrous oxide emissions during storage might result in higher nitrate leaching and ammonia volatilization during field application. So we should have to think more rationally so that shifting to other alternative yields us some progress rather than loss.

Grossi *et al.* (2019) (Grossi *et al.*, 2019) have reviewed different mitigation strategies and their mitigation potential given by different researchers and summarised. Three major strategies have been considered *viz.* Enteric fermentation, Manure storage and Animal management. Under these heads, different categories of strategies have been discussed and their potential of mitigating Methane and Nitrous oxide emissions have been realised. It is observed that for enteric fermentation, electron receptors in the metabolism have the high potential to reduce methane emissions. For manure storage, anaerobic digestion, decreased storage time and frequent manure removal have the high potential to guard the climate from methane as well as Nitrous oxide emissions. In case of devising strategies for animal management, genetic selection seems to be the most effective category with which we can avoid methane releases in the atmosphere.

Feed additives to reduce methane production:

Among so many researched compounds, there are two feed additives that have been proven promising so far and they are 3-Nitrooxypropanol (3 NOP) and Nitrates. A review by Kebreab and Feng (2021) (Kebreab and Xiaoyu, 2021) has summarised that the 3 NOP seems to effectively controlling methane emissions. The effect was positively associated with dose, and negatively associated with dietary fiber content. Moreover, NOP had stronger anti-methanogenic effects in dairy cattle than in beef cattle as the overall mitigating effect of 3NOP was 32% at 127 mg/kg inclusion level. In dairy cattle specifically the impact was 41% reduction while in beef cattle it was 22.4%.

The Nitrate is also a promising feed additive to nullify the methane emissions. When added with diets, the reduction of nitrate to ammonia will be more favourable than methanogenesis inside the gut of the animal. Thus the Hydrogen which was hitherto combining with Carbon dioxide will now make bonds with nitrate and reduce it to ammonia thereby reducing enteric methane production. There are other additives that can prove beneficial in this case like Monensins, Lipid supplements, Mixture of lauric acid, myristic acid and linseed oil, so more research is focussed on these and some other compounds. It has also been seen that the amount of Lignin in the feed can result in high methane production, so the quantities of lignin can be checked too.

There are certain additives which reduce the methane emissions from the stored manure, but we are not yet very clear about the imoact of such substances. Biochar, has been for example found to be effective in reducing methane emssions in some research while in the others it was found that it was not effective (Kebreab and Xiaoyu, 2021).

Organic farming and climate conondrum:

By now, it is clear that agriculture has unequivocally been a major contributing factor for the climate change. As mentioned, it is responsible for 19 per cent of the total GHG emissions. But, as the governments are promoting and shifting towards organic farming, we must keep in mind that this does not result in pollution swapping. As organic farming mainly involves the use of indegenous cows, their urine and dung as manures, fertilizers or pesticides, we must ensure that the products hence made are carbon free. So we have to just not shift towards organic but ‘Regenerative organic’ where we have good nourished soil, carbon and methane free manure and an overall balanced environment. Regenerative agriculture is a holistic systems approach that starts with the soil, and also includes the health of the animals, farmers, workers and community. To have clean inputs for organic farming, lot of reseach is required to make feed additives or manure additives so that livestock raising doesn’t cost us the climate change. An article by reporter, writer and editor Lisa Elaine Held in the Februrary, 2020 edition of FoodPrint (a project of GRACE Communications Foundations) talks about the dangers of organic farming if no proper attention is paid towards what it might bring as the side effects.

The bottomline:

We are heading towards a dangerous future. It is not the time to wait and think but do. We have started bearing the repurcussions of climate change and it is important to change our direction. Amalagamated efforts of Researchers, Innovators, governments, investors are required to mitigate this very huge problem. It is imperative to devise certain mitigation strategies in order to combat this conondrum of climate change. It is an huge immediate reponsibility of agricultiral scientists to respond quickly to prevent a likely disaster in a not very distant future. Inter-disciplinary research can prove itself to be very fruitful during these times. All the techies, agri-experts, veterinarians, chemists, extensionists should collaborate to think and develop innovative mitigation strategies which can provide efficient and effective results. It is a fact that over 40 per cent of the climate change is caused by 16 percent of the richest population. So richer countries and richer people should be the ones to invest more and more research on the topic so that the destitute does not suffer. Every nation should watch its carbon print so that proper actions can be taken in time. We have to join together to fight against these serious problems like climate change, poverty, inequality, human rights, medical ailments and the like. In this world, we cannot just think of our own one nation and proceed. We will have to follow the policy of strength in unity. We all need to come together as a strong force to mitigate these problems. We need to be motivated and contribute in creating awareness about these problems. Only then we can hope for the change for the better.

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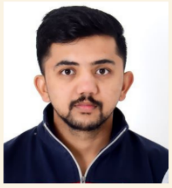

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