FIT Review

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FIT to Market Opportunity Review

CLIENT	**University of Manitoba**
TITLE	**Turning Agricultural Waste into Functional Materials for Environmental Monitoring and Sustainable Energy**
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FUENTEK NUMBER	UMT-0001-FIT
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DATE	9/12/2023



This report is meant to provide guidance to the client in developing a disposition decision for the commercialization of the subject technology and identifying appropriate next steps. The associated analysis was performed in a limited amount of time and the report contains a synopsis of the information gathered during that time period. Therefore, this report is not an exhaustive analysis and should not be viewed as such. Additionally, no information contained herein should be considered legal advice.

Technology Opportunity Information

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Technology Opportunity Summary

A team of researchers from the University of Manitoba and other university and industry partners proposes to identify novel ways of redirecting biomass waste into functional technologies and materials for use in batteries, supercapacitors, sensors, and structures. Their team also proposes to develop new technologies that will contribute to sustainable agriculture production through more controlled fertilizer usage, electrification of agricultural equipment, and crop storage monitoring.

The convergence of several trends results in a very strong potential opportunity for the envisioned research initiative. The global population is growing at a staggering rate and is expected to reach 10 billion by the end of the century, which has prompted increased demand in food security and agricultural production. Current estimates suggest that global food production will need to increase by as much as 68% by 2050 to feed the growing population. In 2030, it is estimated that the current water supply will fall 40% short of meeting global water needs. Global and Canadian efforts to reduce greenhouse gas (GHG) emissions (10% of which are estimated to come from the agri-food complex in Canada) to address climate change provide a very strong impetus, as does the current and projected future shortage of labor in the agriculture sector. Specifically in Canada, more than 5 million tons of biomass is generated annually in Manitoba from agricultural and forestry waste. Over half of this waste is transformed into biofuels, but there remains a need for repurposing the remainder. The use of sensors, computers, GPS, automation, etc. is increasing rapidly in agriculture in applications such as precision agriculture, grain quality monitoring, etc. and there is a growing recognition of the detrimental effects of toxins that may arise during grain storage.

There is a growing need to address these challenges and provide effective ways of repurposing and reusing organic waste, increased crop yield and health, more efficient resource allocation, and increased agricultural sustainability. There is also an opportunity to address the current labor shortage in the agricultural sector using electric and autonomous technologies.

Although the present initiative is targeted at the use of agricultural waste to address needs in Canadian agriculture, it must be noted that once developed, many, if not all, of the resulting technologies are likely to have additional applications in other markets as well.

Analysis Overview



Industry Overview

To proceed with the analysis, five target markets were identified based on the goals of the planned research initiative. All five (agricultural sustainability, cellulose and fiber extraction, energy materials and electrification, sensing and monitoring, and structural materials) are currently growing with demand for technological innovation both generally and within the agriculture industry.

Agricultural Sustainability

In 2022 in Canada, the agriculture and agri-food system employed 2.3 million people (1 in 9 jobs in Canada) and generated $143.8 billion of Canada's gross domestic product (GDP). There are nearly 200,000 farms in Canada that cover 62.2 million hectares, and the average farm size has nearly doubled over the last 50 years due to consolidation and technological advancements.

The global market for sustainable agriculture is USD 12.09 billion and it is growing rapidly at a CAGR of 10.17%, due to greater consumer demand for transparent and sustainable farming practices, increased regulations on pesticides and synthetic chemicals, greater need for effective resource allocation and technical innovation. Current trends in agricultural sustainability focus on waste reduction/reuse/recycling, circular agriculture, minimizing the use of synthetic fertilizers and pesticides, and reducing greenhouse gas emissions.

Proper agricultural waste management methods are vital to preventing nutrient losses and reduced soil fertility, and current methods focus on composting, biogas generation, mulching, biomass conversion, and recycling packaging materials. Many larger companies currently hold the dominant market share in sustainable agriculture, including BASF, Corteva Agriscience, The Mosaic Company, AGCO Corporation, Monsanto Company, Deere & Company, Cargill, and Yara International.

Cellulose/Fiber Extraction

Cellulose fiber is extracted from chemically processed wood pulp and can be used in many applications such as thickeners, stabilizers, and emulsifiers. The USD 40.56 billion market is growing at a projected CAGR of 9.67% due to increasing consumer demand for sustainable alternatives to petrochemical and synthetic fibers. Regenerated cellulose, a specific type of cellulose fiber that is produced in a natural and sustainable way, currently holds a significant portion of the overall market share at USD 18.0 billion. The growing demand for sustainable fiber alternatives has driven many key chemical players including Eastman, Ashland, Dow, and Rayonier to break into the market and they now hold a dominant share. Smaller companies are also breaking into the relatively new market space, including Birla Cellulose, Bacterial Cellulose Solutions, and Sappi Group.

Energy Materials & Electrification

The global powered agriculture market, which includes electrified farming equipment and tractors as well as smaller equipment, reached USD 57.39 billion in 2021 and is expected to continue growing. The high demand for powered agriculture can be attributed to the desire to improve crop yields, operational efficiency, and cost-effectiveness on farms. Within the overall powered agriculture market, the electric farm tractors market is currently estimated at USD 98.7 million due to growing environmental concerns and the efficiency increases offered by electric vehicle technology. Many global governments are introducing incentives and subsidies, including financial grants and tax exemptions, to encourage the switch to electric

vehicles. Achieving zero emissions is a recent push of the Canadian government, and electric vehicle technology is an important component. Many companies, including established players such as John Deere and AGCO and newer players such as Solectrac, Monarch Tractor, and Autonomous Tractor Corporation, are gaining market share in electric technology.

Sensing & Monitoring

Agricultural sensor technology serves many purposes, including monitoring farm conditions to ensure optimal growth conditions and identifying pesticide and mycotoxins present in feed and crops. The USD 1.28 billion mycotoxin feed testing market is expected to grow with the aid of agricultural sensing technology at a CAGR of 7.2%. In 2018, when 121.3 million kilograms of active ingredients were sold as pest control products, 71.1% of all pesticide sales in Canada were agricultural sector products.

Unmanned aerial vehicles (UAVs) are expected to be an important component of agricultural sensing technology due to the enhanced sensing and imaging capabilities provided. The agriculture UAV market is expected to reach USD 5.89 billion by 2030, owing to the rapid technological development of UAVs. Key players including SGS SA, ALS Limited, Sillikar, AsureQuality Limited, and Neogen Corporation all hold a dominant market share globally.

Structural Materials

Another use of cellulose fiber and agricultural waste is the creation of lightweight materials with enhanced sustainability. These materials have applications in a wide range of fields, including construction, biomaterials, and functional materials for transportation or aerospace. The USD 355.9 billion Canadian construction market includes key players SNC-Lavalin Group, Fluor Corporation, Kiewit Corporation, Aecon Group, PCL Constructors, and Bird Construction, who all place a heavy emphasis on developing sustainable materials technology.

Needs Summary

Agricultural Sustainability

Agricultural sustainability faces challenges including the high upfront costs required to implement new technology, which may be prohibitive for some farmers. The high demand by consumers for sustainably produced food puts pressure on governments and farmers to implement sustainable regulations and practices. There is also a current need for effective methods for conservation and preservation of natural resources, including soil and water.

Cellulose/Fiber Extraction

Increasing global urbanization and consumer purchasing power have created increased demand for high-quality textiles and apparel. However, the high cost and diminishing cotton supply have hindered the widespread adoption of cellulose fiber-based materials and textiles. The raw material prices of cellulose fiber change on a regular basis, which limits their reliability for large-scale applications. Significant investments in knowledgeable workers, specialized machinery, and research and development funding are needed to generate new technologies in this area.

Energy Materials & Electrification

The widespread acceptance of electric vehicle technology is hindered by the hesitation from many farmers due to high upfront costs, lack of charging infrastructure, and distrust of electric vehicle technology. For many farmers to feel comfortable investing in electric vehicle farm equipment, there needs to be an increase in the battery power equivalent to the power provided by current diesel engines. Many tractors and other

farming equipment weigh many combined tons, and current electric vehicle technology is not equipped to adequately handle that much weight. Poor Wi-Fi connectivity in rural areas is also a concern, especially for autonomous or remotely operated equipment, which are industry trends that are particularly well-suited to electric vehicles. The agricultural industry is also facing a labor shortage, both now and into the future so if electrification of agriculture equipment helps address that need, it is likely to find greater acceptance. In the near-term, such equipment is more likely to be for smaller vehicles, modular systems for automated tasks, etc.

Sensing & Monitoring

The transportation, handling, and storage of forages and feeds is a significant component of crop and livestock operations, and improper storage and handling can lead to substantial losses. A key cause of spoilage is mycotoxin contamination, so monitoring that is a key need. The current methods of mycotoxin testing, including ELISA-based analysis, are designed for detection of specific types of samples, and need specialized expertise to be able to transition to detection of new types of samples or to cast a wider net of analysis. The current mycotoxin occurrence globally is estimated at 60-80% of all grain samples, so there is a need for rapid and effective detection of multiple types of mycotoxins and pesticides. Precision agriculture also requires a variety of new and improved sensors.

Structural Materials

Recycling and reuse of biomass wastes into value-added applications including structural materials has gained attention in recent years but is yet to be widely adopted. Around 40% of all global carbon dioxide emissions originate from the construction and use of buildings. In the construction industry, excessive use of river sand adversely impacts environmental sustainability and reduces conservation of natural resources. Agricultural waste has been shown to be a viable alternative for sustainable building materials, but extensive research and development still needs to be conducted to provide its efficacy. Agricultural structures include not only buildings but any structure using in connection with the production, harvesting, storage, drying, or raising of agricultural products including livestock, such as fencing, livestock housing, produce containers, etc.

Potential Partners

- Aecon Group
- AGCO Corporation
- ALS Limited
- Amos Power
- Ashland
- AsureQuality Limited
- Autonomous Tractor Corporation
- BASF
- Bacterial Cellulose Solutions
- Birla Cellulose
- Blue Leaf
- Cargill
- Climate LLC
- Corteva Agriscience
- Dow
- Eastman
- EllisDon Corporation
- EnviroLogix Inc.
- Erisha Agritech
- Fendt
- Fluor Corporation
- General Electric (GE)
- General Motors (GM)
- Graham Group
- ImagoAI Inc.
- John Deere & Company
- Kiewit Corporation
- Kubota Corporation
- Monarch Tractor
- Monsanto Company
- Mosaic Company
- Neogen Corporation
- New Holland
- PCL Constructors
- Premier Analytical Services

- R-Biopharm
- Rayonier
- Romer Labs
- Sappi Group
- SGS SA
- Sillikar
- SNC-Lavalin Group
- Solectrac
- Stella-Jones
- Symbio Laboratories
- Toyota
- Vale Industries
- Yara International

Value Proposition

The University of Manitoba plans to bring together university researchers, students, producers, government agencies, and industry representatives to collaborate and share ideas on how to improve agricultural sustainability in Canada by repurposing biomass into functional materials for energy conversion and storage, environmental sensing and monitoring. This effort will focus on four different areas of innovation:

- Redirection of biomass waste to technologies and materials where bio-carbon can be fixed
- Monitoring technologies for fertilizer use and grain storage
- Replacing fossil fuels through the electrification of tractors and farming equipment
- Supply chain improvement for meeting resource needs

Experts in fiber and cellulose extraction for agriculture and food production, energy materials including biomass in batteries and supercapacitors, biomass-based sensors and microfluidic devices for monitoring, and structural materials made from biofiber and biomass composites will be in attendance at the conference.

Conclusion

The research objectives proposed by the team at the University of Manitoba are well-designed to meet current market needs in sustainable agriculture, cellulose and fiber extraction, electrification of farm equipment, sensing and monitoring, and structural materials. The growing demand for enhanced sustainability in farming practices, efficient resource allocation, effective repurposing of organic waste, and increased crop yield and health validates the areas of innovation proposed by the research team. The involvement of a wide range of experts in many fields relating to agricultural sustainability will likely produce favorable outcomes for many of the current market needs.

Recommended Next Steps

The following steps are recommended:

- Review the material in the Additional Information section of this report in detail, capturing additional insights that may inform research, development, and partnering efforts. It may be helpful to allocate this work to various team members according to their interests. Analyze the insights gained from that and this report further to develop detailed strategies for the proposal, the research, and technology development.
- Plan from the start for potential joint intellectual property to arise out of the initiative and have in place adequate inter-institutional and/or other agreements to ensure adequate protection of intellectual property for all parties involved.
- Continue research and development efforts to advance core innovation goals, focusing on innovations that are most likely to meet key needs but will also be cost effective and easy to adopt. For instance, focus on developing innovations that support non-tractor agricultural electrification needs as those are likely to be less costly and less risky to adopt, providing a learning curve that leads to greater acceptance. Similarly, a focus on meeting the needs of agricultural structures other than buildings may provide an easier path while still being impactful in achieving sustainability goals.
- Cost effectiveness of solutions will be key, so make reasonable efforts to quantify performance and cost estimates as part of the research initiatives. This information will be vital to enlisting partners to move technologies forward into usage.
- If possible, also try to determine the types of emissions, costs, and water usage avoided as a result of the use of technology developed; for instance, using biomass on-site rather than transporting it to a biofuel facility. This will enhance the understanding of the potential attractiveness of the technology. It is not necessary to quantify these items at this time, but identifying them may be useful.
- Pursue partnerships with companies as needed to further research and development goals. Those listed in this report can form the basis for this outreach, but the list should be augmented as a deeper understanding of the overall situation develops over time. Canadian companies working in sustainable agriculture that may be of particular interest include SNC-Lavalin Group, Stella-Jones, Western Grains Research Foundation, Vale Industries, and Fluor Corporation.
- Pursue intellectual property protection on new intellectual property generated as a result of proposed collaborative efforts as needed to make the transition to the marketplace economically viable.
- Communicate effectively in outreach to potential partners/customers/influencers, clearly (but concisely) articulating the benefits and applications of technologies developed. Learn and use industry terminology (e.g., “regenerative” vs. “sustainable” vs. “circular” agriculture). For instance, be careful to distinguish the agricultural biomass that is the subject of this research initiative from “agricultural waste”, which by definition includes packaging materials, agrochemical containers, etc.
- Investigate specific financial incentives available to farmers and others that may influence the types of solutions sought or research priorities.
- If technologies suitable for founding a startup are identified, be aware that Ag Tech is currently one of the most under-invested subsectors in the global startup ecosystem and may therefore be attractive to investors.

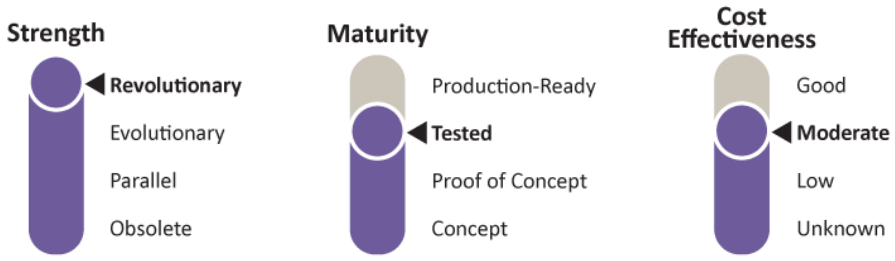
Additional Resources

While conducting this analysis, the following resources were identified in addition to those listed in the Additional Materials section:

- Canada's Agri-Tech Business: https://www.investcanada.ca/industries/agri-tech
- Additional Farming Companies in Canada: https://www.lusha.com/company-search/farming/112/canada/193/page/2/
- Overview of Canada's Agriculture and Agri-Food Sector: https://agriculture.canada.ca/en/sector/overview
- Export Tips and Trends for Canada's Agriculture and Food Industry: https://www.edc.ca/en/article/export-tips-trends-canadian-agriculture-food.html
- Canada Joins International Sustainable Agriculture Production and Food Systems Coalition: https://www.canada.ca/en/agriculture-agri-food/news/2022/01/canada-joins-international-sustainable-agriculture-production-and-food-systems-coalition.html

Factor Analyses

Technology Need Assessment



Agricultural Sustainability

Sustainable agriculture technology revolves around the effective reuse and repurposing of organic waste for value-added applications. There are several methods for repurposing and reusing agricultural waste, the most common of which is composting. Composting is an effective solution for managing agricultural waste that decomposes into nutrient-rich compost and can be formed into organic fertilizers to improve soil fertility, increase crop productivity and yield, and reduce the need for harmful synthetic chemical fertilizers whose production contributes to climate change. Composting can be practiced in both small-scale and large-scale farms.

Technology Need Strengths

- **Increased sustainability** – repurposing and reuse of organic waste provides environmentally friendly solution; biogas production and biomass conversion reduce overall carbon emissions
- **Lower cost** – agricultural waste is a low-cost raw material
- **Greater crop yield and health** – improved methods of agricultural waste repurposing contribute to increased yields and optimal growing environments

Technology Need Weaknesses

- None identified

Biogas production is another agricultural waste processing method, which has proven effective recently in developing countries which are resource limited. Biogas digesters can be planted into the soil in rural areas to convert waste into biogas, which is a renewable energy source that can be utilized for electricity generation purposes. Biogas production also improves living conditions by providing access to cleaner energy production, which reduces air and water pollution and improves overall quality of life. Anaerobic digestion systems, in which bacteria break down animal manure and other organic waste in controlled, oxygen-free environments, are currently the most effective method of producing biogas. These digestion systems can also produce organic digestate, which can be used as a nutrient-rich crop fertilizer, as a byproduct along with biogas. These systems help to capture and recycle nutrients in a closed-loop system to enhance soil health, improve crop growth, and reduce the overall carbon footprint.

Mulching is a method for repurposing solid agricultural waste (including straw, hay, leaves, and crop residues) that protects the soil from erosion and temperature fluctuations. Mulching helps to conserve soil moisture, suppress weed growth, and enhances nutrient retention which improves the overall quality and yield of crops. Decomposition of the mulch over time also improves soil quality.

Biomass conversion is another method for repurposing agricultural waste that transforms waste into value-added products including biofuels, biochemicals, and biomaterials. Some of the most common techniques for biomass conversion include combustion, fermentation, pyrolysis, and gasification. These techniques are being refined and explored further to expand the potential products available from biomass conversion including polymers, construction materials, and biosensors. Recent studies have shown the potential of waste-derived biopolymers derived from cellulose and keratin to have excellent mechanical properties and have the potential to enhance seedling development as compared to conventional substrates.

Fiber & Cellulose Extraction

Cellulose is an abundant natural polymer found in plants that is non-toxic, flexible, renewable, and exhibits high biocompatibility. Regenerated cellulose is a processed form of cellulose that results in a molecular structure with improved crystallinity and has greater applications in gel and thin film applications due to its hydrophilicity. Regenerated cellulose also exhibits high compatibility with other materials, allowing for the combination with other compounds to create new materials with enhanced properties.

Hydrogels and controlled release fertilizers made from regenerated cellulose can be used in many sustainable agriculture applications including water reservoirs for crops, pesticide release, phyto-pharmaceuticals, and controlled nutrient release into soil. The high hydrophilicity of cellulose helps maintain soil and crop moisture, and its surface chemical properties are easily modified to control the fertilizer or pesticide release to contribute to a lower rate of plant death, improve fertilizer retention in soil, and increased plant growth rate. Cellulose-based hydrogels and fertilizers exhibit high water holding capacity, low cost, biodegradability, and are environmentally friendly. These hydrogels can be either soluble or insoluble depending on the application. The amount of moisture retained in the soil has been shown to be highly dependent on the concentration of cellulose-based superabsorbent matrices.

Technology Need Strengths

- **Increased sustainability** – can be used in sustainable agriculture applications to conserve resources and improve crop health and yield
- **High biocompatibility** – safe for crop use
- **Compatible with other materials** – can be combined with other compounds to create new materials with enhanced properties
- **High Demand** - Many applications for processed cellulose including hydrogels, fertilizers, phyto-pharmaceuticals, and controlled nutrient release technologies
- **Low-cost raw material** – cellulose is a low-cost, abundant raw material

Technology Need Weaknesses

- **Cost of production** – High capital costs and processing costs vary unpredictably due to availability of workers and equipment
- **Relatively unproven –** lack of thorough testing and widespread adoption

Energy Materials & Electrification

There have been promising developments around battery technology for electric tractors and other agricultural vehicles. Lithium-ion batteries offer increased energy storage capacity and affordability, while nanotechnology including gold nanowire electrodes and solid-state batteries offer improved performance, safety, and durability. New technologies such as sodium-ion batteries and sodium-sulfur batteries also show promise for electric tractors. The innovation in battery technology is essential for achieving lower costs, faster charging, and longer driving ranges, which could drive the widespread adoption of electric tractors.

Another crucial development in the electric tractor and farm equipment sector is the enhancement of wireless connectivity. The long-range wide area network (LoRaWAN) provides a low-power, long-range wireless communication protocol for tractors, enabling real-time monitoring of performance, precision agriculture practices, and remote control of tractor parameters. The implementation of 5G networks is expected to enable faster data rates even in rural locations. Large-scale farms can leverage centralized data aggregation, real-time monitoring, and predictive analytics to enhance productivity and efficiency. Autonomous electric vehicles could exchange high-quality video data with the high bandwidth and low latency that 5G coverage offers. The increasing compatibility of electric farm tractors with other advanced technologies including GPS guidance systems, automatic steering technology, and telematics allows for capabilities including precise field mapping, optimized seed planting, autonomous navigation, and remote monitoring.

Technology Need Strengths

- **New solutions for battery technology & wireless connectivity –** novel battery and networking technologies enable greater connectivity
- **Energy efficient** – electric vehicles produce no carbon emissions
- **High compatibility –** electric vehicle technology is highly compatible with GPS, autonomous vehicle technology enabling new capabilities

Technology Need Weaknesses

- **Relatively unproven –** lack of thorough testing and widespread adoption
- **High upfront cost of electric vehicles -** EVs provide cost savings with long-term use but require initial capital expenditure
- **Limited battery power –** high combined weight of farming equipment requires increase in battery power than what is currently available
- **Lack of charging infrastructure** – a sufficient number of charging stations may not be available
- **Unreliable network connectivity** – Wi-Fi connectivity limited in rural areas, necessary for

Agricultural Sensing & Monitoring

Recent trends have shown a rapid increase in Canada in agrochemical and pesticide use, and as a result, monitoring technologies that can effectively analyze quantities of mycotoxins in feed and crops are needed. Immunoassays including ELISA and dipstick or lateral flow devices are often used for this purpose, as they are simple to operate and widely used in developing countries. However, these kits are highly sensitive to particular applications, and often cannot be accurately used for the specific commodity needing to be tested. If these kits are used in cross-purpose applications, there may be cross-reactivity and the number of false positives that arise may increase. There are greater efforts to develop multi-toxin screening assays that can detect the presence of more than one type of mycotoxin, including aflatoxins, fumonisins, and deoxynivalenol. However, the initial sensitivity of these rapid tests is low compared to the results available from quantitative analysis in laboratories.

Technology Need Strengths

- **Increased resource allocation** – monitoring technologies allow for optimal water, fertilizer and pesticide quantities, avoiding overuse
- **Greater crop yield and health** – monitoring technologies can help ensure optimal conditions for crop growth
- **Improved sensing capabilities –** ability for real-time monitoring of many variables necessary for optimal growing conditions

Technology Need Weaknesses

- **Relatively unproven –** lack of thorough testing and widespread adoption

Smart sensor technology provides a compact and cost-effective way to monitor and record real-time data on soil moisture and humidity, as well as air moisture and humidity. Sensor technology can help to maximize crop yields and conserve resources by ensuring the environment is optimal for growth and adjusting as necessary. Smart sensors specifically can be used to diagnose problems in the crops, soil conditions, or pesticide levels early enough to remedy the issue before resources are lost. Smart sensors can also send real-time readings of environmental conditions to a centralized database through an adequate Wi-Fi connection, so other farmers can have access to precise knowledge and patterns on farm conditions in certain areas. New sensor technologies being developed include on-plant sensors (plant wearables) using graphene-based and Fiber Bragg Grating (FBG) sensors, and the expansion of existing sensor technologies to include multispectral and hyperspectral imaging. These new capabilities allow for broader monitoring capabilities and greater access to data necessary for improving crop quality and yield. Unmanned aerial vehicles (UAVs) are also increasingly used to monitor crop fields and crop production, which typically include remote sensing and imaging capabilities to detect potential issues.

Some of the important variables that agricultural sensor technology can monitor are air temperature and humidity. Each plant has an optimal temperature for growth, flowering, and fruiting. Photosynthesis increases as the temperature rises, while transportation of sugars occurs during the night or when the temperature is lower. The ability to monitor the air temperature and potentially allows farmers to provide the crops with optimal temperatures (e.g., in greenhouses or other enclosures) depending on their individual compositions. Air humidity also can affect germination and flowering, and the amount of water vapor in the air needs to be in an optimal range for adequate growth. If the humidity is too high, it causes difficulty with plants absorbing water and oxygen from the soil and can contribute to disease. If the humidity is too low, plants can dry out and reduce their ability to take in carbon dioxide.

Soil temperature and moisture are also important variables to monitor for adequate crop growth. Soil temperature directly affects the growth of plants and the rate of germination of seeds. The reaction time of metabolic processes in plants shortens, the rate of chemical reactions increases, and the amount of water

lost through evaporation increases at higher temperatures. Soil temperatures above 30 degrees Celsius have been shown to decrease yield by 25%. To ensure higher crop yields and higher quality of crops, it is vital that the soil temperature be measured and kept cool. Soil moisture and consistency gives an indication of water stored in the soil, which is necessary for the growth of plants. Large-scale studies have shown that crop yields increase by 10% when the soil moisture content is maintained above 50%, while crop yields decrease by 30% when the soil moisture content is below 30%. Monitoring soil moisture and adjusting irrigation requirements is an effective way to increase overall plant health and crop yields.

Structural Materials

Cellulose is commonly used in advanced materials and sensor fabrication due to its multifunctional features. Cellulose is suitable to develop sensors and biosensors for detecting analytes and physical changes because of its molecular structure. Cellulose exhibits long-range structural organization which promotes high processability, surface functionalization and compatibility with nanomaterials. Cellulose is an alternative to traditional petrochemical-based polymers due to its renewability, biocompatibility, biodegradability, availability, and ability to form highly transparent, flexible, and foldable films. Smart polymeric systems have contributed to the agricultural industry by increasing the efficiency of pesticides, herbicides, and fertilizers by allowing controlled release systems, which promotes conservation of resources. Some polymeric materials have been used as soil conditioners to control drought conditions, and other polymer materials have been used for plant bioengineering to increase productivity and disease resistance.

Technology Need Strengths

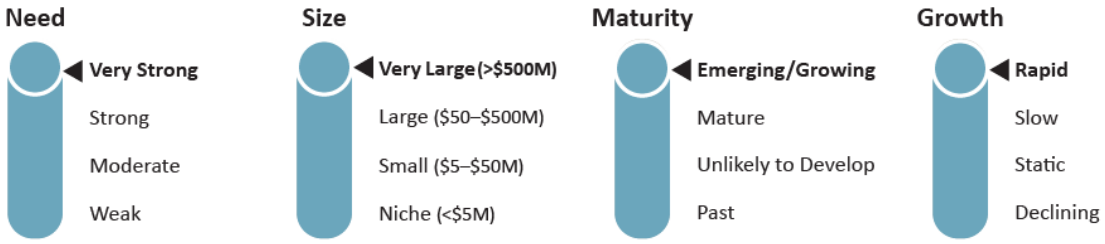
- **Increased sustainability** – repurposing and reuse of organic waste provides environmentally friendly solution
- **Lower cost** – agricultural waste are low-cost raw materials
- **Comparable properties to traditional construction materials** – construction materials made from agricultural waste have comparable physical and thermo-mechanical properties

Technology Need Weaknesses

- **Relatively Unproven –** lack of thorough testing and widespread adoption

Agricultural waste can also be used to create alternative construction materials with increased sustainability and improved energy safety. Traditional construction materials including concrete and asphalt use excessive amounts of natural and river sand, which adversely affects environmental sustainability. Additionally, the production of cement (a primary ingredient in concrete) is one of the main producers of carbon dioxide, which is a potent greenhouse gas. Construction materials made from agricultural waste have been shown to provide comparable physical and thermo-mechanical properties to traditional construction materials, with improved ecological impact.

Market Need Assessment



This section provides a summary of the research findings presented in Market Research Results within the Additional Information section.

Sustainable Agriculture

Market Needs

Currently, trends in agriculture sustainability focus on transparency, circular economies and circular agriculture, and reducing greenhouse gas emissions. Circular agriculture refers to the process of minimizing inputs of concentrated feed and chemical fertilizer, reusing agricultural waste, and closing nutrient loops. Advanced technologies, including artificial intelligence (AI), could help increase sustainability in agriculture as well. It is predicted that AI technologies alone could reduce worldwide greenhouse gas emissions by 4% in 2030 throughout the agriculture, water, energy, and transportation sectors.

Conventional farming activities typically generate large amounts of agricultural waste. Agricultural waste includes a wide range of organic and inorganic materials including crop residues, animal manure, waste feed, agricultural chemicals, and packaging that are typically discarded after agricultural processes like crop production or livestock farming. Agricultural waste is biodegradable and nutrient-rich and can be a resource to produce other value-added applications such as advanced materials or sensor technologies. However, if agricultural waste is not managed properly, it can lead to water pollution, reduced soil fertility, and climate and human health impact.

Market Need Strengths

- **Large and growing market** – repurposing agricultural waste and biomass is expanding rapidly
- **Strong demand** – growing consumer demand for increased sustainability and transparency across agricultural sectors
- **Significant R&D investment** – many types of companies are investing in sustainable agriculture technologies
- **Federal regulations on agricultural waste –** provides incentives for repurposing agricultural waste

Market Need Weaknesses

- **Many large players already engaged** - could make market entry challenging
- **Uncertain cost competitiveness** – high cost of current sustainable technologies
- **High upfront costs** – implementing new technology and overhauling current systems

Currently, agricultural waste management focuses on waste reduction, recycling, and reuse. These strategies include composting, biogas generation, mulching, biomass conversion, and recycling packaging materials. However, if not performed properly, these waste management techniques can lead to nutrient losses and

reduced soil fertility. New agricultural waste regulations from international organizations including the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) are focused on promoting sustainable agricultural waste management practices and reducing agricultural emissions.

The global sustainable agriculture market was estimated at USD 12.09 billion in 2021 and is expected to grow to USD 28.91 billion in 2030, growing at a CAGR of 10.17% during that period. The strong growth of this market is due to the growing demand for sustainably produced food, increasing government support and regulations, and rapid technological advancement. Sustainable agriculture refers to a holistic approach to farming that aims to create a system that is environmentally, socially, and economically sustainable. This involves using farming practices that minimize the use of synthetic pesticides and fertilizers and working to reduce food waste and food insecurity. Regenerative agriculture is closely related to sustainable agriculture but aims to restore farming land by improving the organic matter and carbon content of the soil, increasing biodiversity, and improving water retention and quality.

Consumers are becoming increasingly aware of the environmental and social impact of their food choices and are seeking out food that is produced using sustainable practices. Global governments are also launching initiatives to promote sustainable agriculture practices that provide funding and support for farmers and researchers to develop and implement sustainable practices. New technological advancements including precision agriculture, vertical farming, and biotechnology allow farmers to produce more food with fewer resources, which reduces the environmental impact of agriculture.

Current challenges to implementing sustainable agriculture practices include the high cost and lower yields sometimes seen with these practices. Many of these practices require significant upfront investment, and some farmers may not have the resources to implement new technology or overhaul their current methodologies. There is an increasing need for conservation and sustainable use of natural resources including soil and water to enhance or preserve these resources and the quality of the environment.

Canada-Specific Market Needs

There is a lack of available market data for Canada-specific needs in agricultural sustainability.

Key Players

The global agriculture sustainability market is dominated by several larger companies holding the majority of the market share. Some of the key players include BASF, Corteva Agriscience, The Mosaic Company, AGCO Corporation, Monsanto Company, Deere & Company, Cargill, and Yara International.

Cellulose & Fiber Extraction

Market Needs

The global cellulose market was estimated at USD 40.56 billion in 2022 and is projected to grow at a CAGR of 9.67% to USD 93.10 billion by 2030. Cellulose is typically used in derivative forms including acetate, cellulose ethers, and cellulose esters. These derivatives can be used as thickeners, stabilizers, and emulsifiers in applications such as pharmaceuticals, food, textiles, and cosmetics.

Cellulose fiber is constructed from chemically processed wood pulp that is derived from plant bark, leaves, and wood. Cotton fiber, rayon, flax fiber, and viscose are all types of cellulose fiber and some of the most common uses include textiles, fabrics, and filters. The global cellulose fiber market is expected to grow from USD 35.20 billion in 2021 to USD 60.01 by 2028, at a CAGR of 9.30% during that period. The growth of this market can be attributed to the increasing demand for environmentally friendly and biodegradable alternatives to petrochemical-sourced fibers. Increased global urbanization and consumer purchasing power is driving a shift from need-based to aspiration-based purchases, including high-quality textiles and apparel.

Market Need Strengths

- **Many applications** – uses of cellulose fiber are expanding rapidly
- **Large and growing market –** increasing adoption across industries
- **Strong demand** – growing consumer demand for increased sustainability and transparency across agricultural sectors
- **Significant R&D investment** – many companies are investing in cellulose processing and regeneration technologies

Market Need Weaknesses

- **Many large players already engaged -** could make market entry challenging
- **Diminishing global cotton supply –** less raw material available to make cellulose fiber
- **Changing raw material prices –** highly variable depending on market conditions
- **High capital costs –** skilled workers and specialized machinery required

High cost, diminishing global cotton supply, and strict environmental regulations have been a hindrance to the widespread expansion of the global cellulose fiber market. Cellulose fiber raw material prices and availability change on a regular basis, limiting their reliability for larger companies. Currently, competent workers and specialized machinery are necessary to produce cellulose fiber, which contributes to the highly capital-intensive nature of the industry. Significant investments in both knowledge and cash are necessary to advance the research and development efforts to generate new technologies.

Regenerated cellulose is a specific type of cellulose fiber that is produced from natural cellulose by physical dissolution and regeneration. The regeneration process is eco-friendly and produces cellulose that is biodegradable in nature, which has applicability in the fabric, automotive, agricultural, and packaging industries. The global regenerated cellulose market was valued at USD 18.0 billion in 2022 and is projected to reach USD 27.3 billion by 2027, growing at a CAGR of 8.7% between 2022 and 2027. The demand for regenerated cellulose is growing due to the adoption of new manufacturing technologies, increasing awareness about personal hygiene and sustainability, and rapid urbanization.

Canada-Specific Market Needs

There is a lack of available market data for Canada-specific needs in cellulose and fiber extraction.

Key Players

The global cellulose and cellulose fiber markets are dominated by many key players in the chemical industry including Eastman, Ashland, Dow, and Rayonier holding the majority of the market share. There is a focus on technological innovation and collaboration in this space, with smaller companies including Birla Cellulose, Bacterial Cellulose Solutions, and Sappi Group also holding a significant market share.

Energy Materials & Electrification

Market Needs

The global powered agriculture market was valued at $57.39 billion in 2021, which is expected to grow with a CAGR of 5.02% and reach $73.32 billion by 2026. Powered agriculture refers to electrified farming equipment and encompasses a wide variety of solutions including tractors, combines, planters, sprayers, tilling equipment, haymaking equipment, and balers. Powered agriculture is increasing in demand due to its ability to improve yield, soil fertility, operational efficiency, and profitability.

Within the overall market for powered agriculture, the global electric farm tractors market specifically is expected to grow at a CAGR of 14.06% from USD 98.7 million in 2022 to USD 234 million in 2028. The high growth of this market can be attributed to greater global environmental concerns, farmer demands for economic productivity, and consumer demand for sustainable on-farm production practices. There is also increased regulatory pressure for sustainability, electric efficiency, and a push toward autonomous electric vehicle technology that can help address current labor shortages. Transitioning to battery-powered, zero-emission electric vehicle technology offers farmers significant reductions in fuel and maintenance costs as compared to traditional diesel-powered equipment of equal capacity. Electric vehicle technology can also reduce the cost of production for farmers by reducing labor requirements and providing on-the-go crop condition data.

Market Need Strengths

- **Very large and growing market –** electric vehicle and powered agriculture markets are growing rapidly
- **Long-term profitability –** switching to electric vehicle technology can conserve resources and save money over years of operation
- **Significant R&D investment –** many types of companies are investing in electric vehicle and battery technology
- **Federal regulations on lower emissions –** provides incentives for transition to electric vehicle technology

Market Need Weaknesses

- **Many large players already engaged -** could make market entry challenging
- **High upfront costs –** transitioning from diesel-based equipment can be expensive
- **Hesitancy from farmers –** unproven electric vehicle technology could discourage early

Global governments are introducing incentives and subsidies to bridge the price gap between electric vehicles and traditional diesel vehicles. The push toward electric farm equipment is driven by concerns over atmospheric pollution caused by combustion engine tractors. Many countries are implementing public charging infrastructures, which enable convenient and affordable access to charging stations. Many countries are also awarding financial grants and tax exemptions to charging station operators and construction projects.

However, there are still hesitations from many farmers about transitioning to electric vehicle technology, mainly due to the initial equipment costs, lack of adequate charging infrastructure, run time concerns, and

distrust of electric vehicle technology in terms of durability and reliability. Many modern agriculture farms utilize many different vehicles and machinery, that can weigh anywhere from a combined few tons to as much as 15 tons. An increase in battery power to half the energy delivered by the equivalent weight of diesel fuel could be vital to increasing implementation and acceptance across farms. There are also issues with Wi-Fi connectivity in rural areas, which is necessary if autonomous electric vehicles are considered. The COVID-19 pandemic also highlighted how fragile the global supply chain is.

Canada-Specific Market Needs

Canada-based farms specifically supply food to hundreds of countries around the world, and its agricultural industry has been identified by the federal government as one of the sectors with the highest economic growth potential. Agriculture in Canada accounts for 6.7% of the total national gross domestic profit and contributes 12.5% of national employment according to the most recently available data in 2016. There are nearly 200,000 farms across Canada, and their machinery contributes to 18% of total agricultural emissions. Zero emissions is becoming a cornerstone of Canadian regulatory policy, which is driving the demand for electric vehicle technology. In Canada, the scale of machinery is another important factor in whether farmers are likely to adopt electric vehicle technology. The power requirements for electric tractor technology to meet the hundreds of horsepower currently provided by large diesel engines to cover thousands of acres are difficult to match.

Key Players

Both established (e.g., John Deere, AGCO) and newer companies (e.g., Solectrac, Monarch) are looking to break into this large market space. There is a focus on technological innovation, and the market is not yet saturated due to the novelty of electric vehicle technology. Other key players in this space include Kubota Corporation, Erisha Agritech, Autonomous Tractor Corporation, and Amos Power.

Agricultural Sensing & Monitoring

Market Needs

Agricultural sensing technology allows farmers to adequately monitor farm conditions including air temperature and humidity, soil temperature and moisture, and mycotoxin or pesticide levels in crops. These measurements help to maximize efficiency of resources including water and fertilizer and produce higher-quality crop yields. Agriculture 4.0 is a new and emerging trend comparable to Industry 4.0, in which systems are being designed and implemented to include drones, robotics, vertical farms, Internet of Things (IoT), artificial intelligence, and advanced sensor technologies. This effort is designed to support autonomous operations and mass customization of farming practices through the integration of digital technologies. By implementing Agriculture 4.0 practices, farms can reduce costs of operation, increase yields, and gain information necessary for minimizing crop damage, fuel, and fertilizer usage.

Market Need Strengths

- **Large and growing market –** agricultural sensing and pesticide detection markets are growing
- **Strong demand –** high number of mycotoxins and pesticides present in crop samples
- **Federal regulations on toxin exposure –** limits amount of pesticides and mycotoxins allowed in crops and feed

Market Need Weaknesses

- **Many large players already engaged -** could make market entry challenging
- **High cost of current testing capabilities –** most accurate method of testing is analyzing each crop sample individually, which requires additional resources

Digital agricultural solutions include unmanned aerial vehicles (UAVs) to optimize operational efficiency, crop production, and crop field monitoring. UAV technology typically includes remote sensing and imaging capabilities to detect soil variation, irrigation issues, and fungal infestations. The global agriculture UAV market is projected to grow from USD 0.88 billion in 2020 to USD 5.89 billion by 2030. The growth of this market is due to the development of new UAV technologies, additional venture funding, and UAV-related government regulations.

Agricultural sensor technology can help to identify mycotoxins in food and crops with a high degree of accuracy and reliability. The global mycotoxin feed testing market is expected to grow from USD 1.28 billion in 2022 to USD 1.80 billion in 2027 at a CAGR of 7.2% during that period. Mycotoxins are naturally occurring toxic substances produced by fungi that can contaminate crops and animal feed, and cause health problems for both livestock and humans. The growth of this market is due to the global increase in incidences of food borne illnesses and the advancement of technologies for quantifying and analyzing mycotoxins. Currently, the most common method of mycotoxin testing is through immunoassay-based testing using ELISA analysis, which has improved in sensitivity and accuracy in recent years. However, the most effective tool for managing the risk from mycotoxins is the systematic testing and rejection of contaminated crops, which requires consistent analysis capabilities to identify more contamination. The current mycotoxin occurrence globally was measured above the current EU limits in 25% of all grain samples, with estimates of detectable levels of mycotoxins in the 60-80% range.

Canada-Specific Market Needs

Pesticides are toxic chemicals designed to control the occurrence of pests and can take the form of insect repellent, wood preservatives, pool sanitizers, and biological compounds. In Canada, there are more than 600 registered active ingredients in more than 7,600 registered pesticide products currently available on the market. In 2018, 71.1% of pesticide sales in Canada were agricultural sector products. The sales of pest

control products in Canada reached 121.3 million kilograms of active ingredients (kg a.i.), up from 101.1 million kg a.i. in 2014. Glyphosate was the top ingredient sold in Canada in 2018, which is one of the top pesticide ingredients globally.

Key Players

The global mycotoxin testing and sensing market is highly saturated with a few key players including SGS SA, ALS Limited, Sillikar, AsureQuality Limited, Neogen Corporation, Premier Analytical Services Inc., and Symbio Laboratories holding the dominant share.

Structural Materials

Market Needs

The growing global demand for sustainable agriculture has led to the development of lightweight materials with broad applications in construction, biomaterials, and functional materials that exhibit increased sustainability, large-scale production, and functional properties. The growth of the construction sector specifically has created a deficit and constraints on natural building materials. It is estimated that around 40% of all global carbon dioxide emissions originate from the construction and use of buildings, 15% of which are associated with the production of construction materials. The excessive use of river sand (used as fine aggregate in concrete) adversely affects environmental sustainability.

Market Need Strengths

- **Widespread market applications –** structural materials made from biomass and biowaste can be used in many industries
- **Large and growing market –** construction materials market is large and expected to increase
- **Significant R&D investment –** many types of companies are investing in research on structural materials made from biowaste or biomass
- **Increased federal regulations –** provides incentives for limiting emissions

Market Need Weaknesses

- **Many large players already engaged –** could make market entry challenging
- **High capital costs –** requires skilled labor and specialized machinery

Agricultural waste is also typically generated through the production of traditional construction materials. However, agricultural waste and the recycling and reuse of biomass wastes has been demonstrated in recent years to be a viable technological solution for building construction materials that could improve sustainability and ease the use of natural resources. Recent research has focused on the extraction of natural polymers from biomass waste, reuse of biomass waste, and preparation of carbon-based materials as novel adsorbents, catalyst carriers, electrode materials, and functional composites. These materials can be prepared from biomass waste from multiple sources including agricultural and forestry, animal, industrial, and municipal solid waste as raw materials at a low cost.

Canada-Specific Market Needs

The construction market size in Canada was estimated at $355.9 billion in 2022 and is projected to grow at an AAGR of more than 1% during 2024-2027. The construction market in Canada is expected to grow due to developments in the industrial, energy, and transportation sectors. Commercial construction is expected to remain steady due to rising inflation, a shortage of skilled labor, and high borrowing costs, but could grow by 2030 due to the government's goal of increasing tourism during that period. Industrial construction is expected to grow due to the strong growth in electric vehicle (EV) technology.

Key Players

The Canadian market for construction materials is market is dominated by a few key players including SNC-Lavalin Group, Fluor Corporation, Kiewit Corporation, Aecon Group Inc., PCL Constructors Inc., EllisDon Corporation, Graham Group Ltd., and Bird Construction holding the dominant share. SNC-Lavalin Group holds the dominant share out of these key players, which could be due to their strong focus on sustainability technology.

Tags

Categories and keywords can be used to improve online searching and portfolio categorization.

Technology Categories

- Agricultural
- Biotechnology
- Chemicals
- Energy
- Environmental
- Food Science & Nutrition
- Manufacturing Equipment
- Materials
- Sensors & Actuators

Keywords

Sustainable agriculture, electrification of farm equipment, electric tractors, electric vehicles, cellulose fiber, regenerated cellulose, agricultural waste repurposing, agricultural waste recycling, mycotoxin sensing, pesticide sensing, biomass waste, agricultural sensors, structural materials from biomass, biogas

Value Chain

The value chain maps the categories of players within a segment of an industry to provide context about the supplier-customer relationships. Understanding the various levels of product supply aids in targeting the appropriate types of companies in commercialization efforts. The highlighting shows where the technology falls in the value chain.

Level	Description	Example Players
 Raw Material	Biomass, agricultural waste, cellulose	Agriculture farms, municipal & agricultural waste management, environmental biomass
 Component	Regenerated cellulose, cellulose fibers, batteries, supercapacitors, sensor components	GP Cellulose, Birla Cellulose, Bacterial Cellulose Solutions, Eastman, Ashland, Dow, Rayonier, Cargill
 Assembly	Agricultural sensors, electric vehicles, cellulose-based construction materials, biopolymers	Fendt, Kubota, New Holland, Solectrac, EnviroLogix, ImagoAI, NEOGEN, R-Biopharm, Romer Labs, Yara International, SNC-Lavalin Group
 Distribution	Electric vehicle providers, construction materials providers, agricultural sensor providers	AGCO Corporation, John Deere & Company, Autonomous Tractor Corporation, Monarch Tractor, General Electric, General Motors, Monsanto
 End Users	Farmers, growers	Industrial farms, small individual farms

Current Market Offerings

Some of the products currently on the market include:

Electric Agricultural Equipment

Company / Web Site	Similar Products	Comments
Fendt https://bit.ly/4434nhT	e100 Vario	AGCO/Fendt has launched the Fendt e100 Vario, a practical, all-electric compact tractor with 50 kW power output, which can operate for up to 5 hours under actual operating conditions. The energy source is a 650 V high-capacity lithium-ion battery with a capacity of around 100 kWh. The battery is charged either with 400 V and up to 22 kW via a standard CEE outdoor socket, or by a supercharging option with direct voltage. With a standard CCS type 2 plug, the battery can be recharged up to 80% in just 40 minutes.
Kubota https://bit.ly/45gBFei	Kubota LX electric tractor	The LXe-261 is equipped with a large-capacity battery that can provide rapid one hour charging and three to four hours of continuous operation. Thanks to this feature, users will be able to quickly charge the batteries during lunch and continue working in the afternoon without losing time. The LXe-261 includes key features for mowing, hauling, and other green space management tasks, such as an independent PTO, a comfortable HST transmission and several hydraulic outlets.
Monarch Tractor https://bit.ly/47n5zzw	MK-V Tractor	Monarch Tractor claims to be the "maker of the world's first fully electric, driver optional tractor." MK-V Tractor combines electrification, automation, and data analysis to help farmers reduce their carbon footprint, improve field safety, streamline farming operations, and increase their bottom lines. Utilizing a Monarch MK-V in place of a comparable diesel tractor is the equivalent emission reduction of removing 14 passenger vehicles from the road. Considering nearly 25 percent of global emissions result from agriculture, the zero-emission Monarch Tractor will help make meaningful emissions reductions as the use of Monarch Tractors scale in an industry that has been historically difficult to decarbonize.
New Holland https://bit.ly/3OwP238	Tractors	2006: Experimented with hydrogen fuel, abandoned but may revisit when cost of hydrogen decreases and infrastructure increases. 2013: Created a working prototype for methane-power tractor. Released T6.180 Methane Power tractor in 2021.

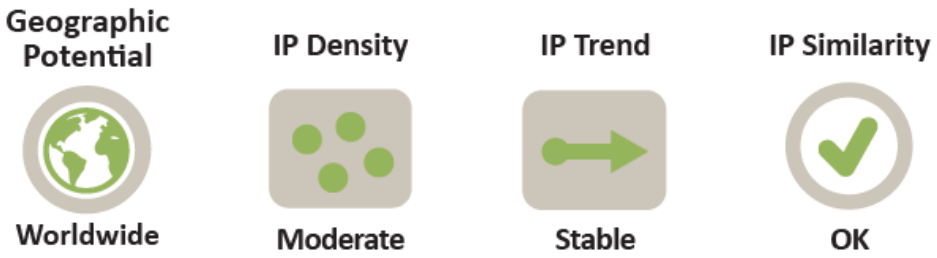
Company / Web Site	Similar Products	Comments
		2022: Presented New Holland T4 electric Power the industry's first all-electric Utility tractor prototype with autonomous features. 2023: Field testing prototype T7 Methane Power LNG, which runs on LNG from processed cow manure. New Holland manufactures tractors of many scales — from a 25-horsepower tractor with low energy demands to a 900-horsepower tractor with high energy demands. Although battery technology is evolving, currently, batteries can only support relatively small tractors. For midsized tractors the most suitable cleaner fuel is CNG. For large machines that demand more power, Baroncelli said the ideal fuel would likely be LNG.
Solectrac https://bit.ly/3OPN27E	e25 and e70N electric tractors	Solectrac is an American tractor manufacturer based in Santa Rosa, California. Solectrac offers 100% battery-powered, all-electric tractors for agriculture and utility applications. They currently offer unique models specially designed for different farming and utility operations: the e25, a 25 HP category compact electric tractor, and the e70N, a narrow 70 HP category electric tractor.

Sensors for Pesticides and Mycotoxins in Grain

Company / Web Site	Similar Products	Comments
EnviroLogix Inc. https://bit.ly/3OScZUk	TotalTox™ testing kits	TotalTox™ testing kits, are fast and easy to use for on-site testing for mycotoxins in grain and grain co-products. TotalTox™ tests were developed to help buyers of grain (grain elevators, corn mills, feed mills, ethanol plants *et al*.) improve their mycotoxin risk management capabilities, while simultaneously increasing their mycotoxin testing operational efficiency. TotalTox™ mycotoxin tests for aflatoxin, DON (vomitoxin), fumonisin and zearalenone are currently available as single strip kits or in a comb format.
ImagoAI Inc. https://bit.ly/441PSuH	Corn Mycotoxin Test	Specification: Sample Type: Corn kernels, Fractional corn Tests: DON, Aflatoxin, Fumonisin, Zearalenone Results Type: Semi Quantitative Test Time: < 30 seconds for 4 Mycotoxins Technology: Hyperspectral imaging and AI

Company / Web Site	Similar Products	Comments
NEOGEN https://bit.ly/3Kzj3OP	Raptor® and Endpoint kits	NEOGEN covers all six major toxins (aflatoxin, DON, fumonisin, zearalenone, ochratoxin, and T-2/HT-2). The company offers both ELISA and lateral flow test kit formats. Within the ELISA platform, it offers solvent extractions, aqueous extraction and high sensitivity kits. Their latest technology offerings are the Raptor® platform and the Endpoint kits. The Raptor reader offers semi-automated testing capability to increase accuracy and reduce user error. The Raptor platform also includes a data manager program and the ability to connect seamlessly with a company's LIMS system Operators can add their sample and walk away while the test strip develops, reads and records the result.
R-biopharm https://bit.ly/45lHDdT	RIDA®SMART APP	The RIDA®SMART APP is a software application for the quantification of RIDA®QUICK mycotoxin lateral flow tests. The RIDA®SMART APP is a complete new evaluation technology for the quantification of mycotoxins. This technology evaluates lateral flow tests (LFDs), which are used for immunochromatographic analysis of mycotoxins. The app provides reliable and accurate results, which can be forwarded via e-mail, exported to a cloud server or easily sent to any supported printer. The app represents a more inexpensive, easier and faster alternative to conventional LFD reading devices. RIDA®SMART APP is compatible with all quantitative RIDA®QUICK mycotoxin tests
Romer Labs https://bit.ly/3ONQ4Z5	AgraStrip® Pro Total Aflatoxin WATEX®	The AgraStrip® Pro WATEX® test system enables the rapid and simple on-site quantification of mycotoxins in a variety of agricultural commodities. Both extraction and assay have been streamlined, reducing steps to a bare minimum while setting new standards in accuracy and usability. The test kits are available in a quantitative format and are used with the AgraVision™ Pro reader, to provide objective results and secure a consistent results documentation.

Intellectual Property Assessment



This section provides a summary of the research findings presented in IP Research Results within the Additional Information section.

Electrification of Agricultural Equipment

The intellectual property landscape for electric agricultural equipment shows a peak of filed patent applications and issued patents in 2012, with a slight decline observed from 2013-2016. Applications remained consistent between 2017 and 2021, and then declined sharply in 2022 and 2023. This could be due to the delay in processing of patent applications during the COVID-19 pandemic. The United States clearly leads the number of applications filed each year, with China and Germany farther behind.

Toyota, GE, GM, and Honda are the most active patent assignees in this area. Many of the companies that have filed patent applications are still active in the technology area and are continuing to file patent applications in recent years. This shows that this is still an active area of research, and many of the patent applications cover technologies that are currently still on the market. The patents in this area focus on electric vehicle technology and methods of controlling movement, voltage control mechanisms, fuel cell vehicles, managing charge storage, hybrid powertrains, and supercapacitor technology.

Key Assignees

While conducting the searches, the following corporate assignees, who may be potential licensees, were identified:

From most patents to least:

- TOYOTA JIDOSHA KK
- GENERAL ELECTRIC CO(Group)
- BAYERISCHE MOTOREN WERKE AG
- GM GLOBAL TECH OPERATIONS LLC
- HONDA MOTOR CO LTD
- DAIMLER AG
- AUDI AG
- BALLARD POWER SYSTEMS
- HPS HOME POWER SOLUTIONS GMBH
- SYSTTIC POWER MFG LLC

Sensors & Monitoring Equipment

The intellectual property landscape for agricultural sensors and monitoring technology grew steadily between 2010 and 2020, with the peak of filed applications occurring in 2020 with 30 applications filed. There has been a decline in issued patents in 2021 through 2023, which could be due to the delay in processing of patent applications during the COVID-19 pandemic. The United States clearly leads the number of applications filed each year, with Germany far behind.

John Deere & Company, Climate LLC, Blue Leaf, and BASF are some of the most active patent assignees in this area and are still active in the technology area and continuing to file patent applications in recent years. This shows that this is still an active area of research, and many of the patent applications cover technologies that are currently still active on the market. The patents in this area focus on solid material flow sensors, agricultural machines, automated soil sensor and grain sensor systems, fertilizer systems, environmental monitoring systems, and novel optical sensors for analyzing constituents.

Key Assignees

While conducting the searches, the following corporate assignees, who may be potential licensees, were identified:

From most patents to least:

- DEERE & CO
- CLIMATE LLC
- BLUE LEAF I P
- CNH IND AMERICA LLC
- CNH IND CANADA
- PRECISION PLANTING LLC
- BASF AGRO TRADEMARKS GMBH
- SYNGENTA PARTICIPATIONS AG
- ROBERT BOSCH GMBH
- BASF AG

Additional Information

The following sections provide additional information used in this analysis:

- Market Research Results
- Intellectual Property Research Results
- Closely-Related Patents
- Closely-Related Publications

Market Research Results

The following are the most relevant and non-redundant market research findings.

Sustainable Agriculture

- **5 SUSTAINABLE TECHNIQUES FOR AGRICULTURAL WASTE MANAGEMENT**

No date | https://www.homebiogas.com/blog/blog-agricultural-waste-management/

AGRICULTURAL WASTE: DEFINITION AND IMPACT

Agricultural waste refers to a wide range of organic and inorganic materials discarded after agricultural processes like crop production or livestock farming. Think crop residues (stalks, rice straw, leaves, or husks), animal manure, waste feed, agricultural chemicals, and all the packaging used in the production and supply chain.

Given the diversity of these materials and the large amounts produced annually, agricultural waste is a double-edged sword. It has enormous potential when appropriately managed because it's biodegradable and nutrient-rich. So, it can become a valuable resource through composting or conversion into biofuels.

On the other hand, the effects of agricultural waste can impact life quality and ruin ecosystems. Improper handling of farming byproducts can lead to water pollution, reduced soil fertility, climate impact, and the loss of valuable organic matter. Plus, it can have significant effects on human health.

So, farms need to implement cost-effective agriculture waste management systems to keep up with food production challenges. The world's population is growing, demanding food security and increased agricultural production. Farming activities will continue to generate large quantities of waste that mustn't end up in landfills. Farmers need to learn to recognize the potential of agricultural waste and adopt eco-friendly strategies for a more resource-efficient world.

TYPES OF AGRICULTURAL WASTES

Crop residues: stalks, leaves, husks, and straw that remain after harvesting wheat, rice, corn, sugarcane, and others

Animal manure: feces, urine, and bedding materials

Agrochemical containers of pesticides, herbicides, and fertilizers

Leftover feed: grains, forages, and other feed materials

Harvest and processing waste: fruit peels, vegetable trimming, damaged or rejected produce, and byproducts from food processing

Packaging materials: plastic bags, cardboard boxes, and containers

Green waste: trimmings, prunings, plant debris, leaves, branches, and grass clippings

WHAT IS AGRICULTURAL WASTE MANAGEMENT?

Agricultural waste management refers to all the coordination, handling, and controlling of the waste generated from agricultural activities. The primary goal is to prevent soil and water pollution, greenhouse gas emissions, and health risks for humans and animals.

An effective agricultural waste management system focuses on one or all of the following techniques:

- Waste reduction
- Recycling
- Reusing

These methods turn waste into valuable resources like organic fertilizers or green energy like biogas. It's a win-win situation for the environment, organizations in the agricultural sector, and the people they serve.

HOW TO USE RECYCLED AGRICULTURAL WASTE: 5 SUSTAINABLE TECHNIQUES FOR AGRICULTURAL WASTE MANAGEMENT

Composting

Composting is an effective solution for managing plant residues, trimmings, manure, and other agricultural products which decompose into nutrient-rich compost. The best part is that it can be practiced in small-scale and large-scale settings — from home gardens to small farms to large agriculture organizations.

Compost and organic fertilizers made with agricultural waste improve soil fertility, increase crop productivity, and reduce (sometimes eliminate) the need for synthetic chemical fertilizers.

Biogas generation

Biogas production has emerged as a highly effective waste management method, especially useful in developing countries. Over the past five decades, governments and non-governmental institutions have supported the implementation of small-scale biogas digesters in rural areas, primarily in Asia, South America, and Africa. These digesters convert waste into biogas, a renewable energy source that can be used for cooking, heating, and electricity generation.

The EU is also improving legislation to facilitate sustainable agriculture practices by encouraging biogas generation as an agricultural waste management solution at scale.

Biogas not only helps manage agricultural waste effectively but also improves living conditions by providing access to cleaner and more efficient energy production, reducing air and water pollution, and uplifting the overall quality of life.

Mulching

Agricultural solid waste used as mulch helps conserve soil moisture, suppress weed growth, and enhance nutrient retention. Mulching protects the soil from erosion and temperature fluctuations, improving crop health and productivity.

The most common and effective agricultural wastes for mulching include straw (wheat, rice, or barley), hay, crop residues (corn stalks, bean vines, or sugarcane tops), leaves, and grass clippings.

Biomass conversion

It includes techniques like thermochemical and biochemical conversion that transform agricultural waste into valuable products like biofuels, biochemicals, and bioplastics.

Some of the most popular biomass conversion processes are:

- Combustion: you can burn biomass to produce heat and electricity. It's more sustainable than burning fossil fuels because the carbon dioxide released during combustion is part of the carbon cycle.
- Fermentation: fermented crops or sugarcane produce biofuels like ethanol or biodiesel. They're a cleaner alternative to fossil fuels in transportation and other industries.
- Pyrolysis: heating biomass without oxygen generates biochar, bio-oil, and syngas. Biochar can be used as a soil amendment, while bio-oil and syngas can be further processed into biofuels and other valuable products.
- Gasification: this partial oxidation process converts biomass into a gas mixture known as syngas. Syngas can be used for power generation or further processed to produce various chemicals and liquid fuels.

Recycling packaging materials

Agricultural operations use various materials, including plastic containers, bags, and packaging, to facilitate crop planting, harvesting, and transportation. While these materials are essential for ensuring efficient and hygienic agricultural practices, their widespread use amplifies the effects of agricultural waste on the environment.

Proper recycling involves collecting, sorting, and processing plastic materials to transform them into new products or raw materials for manufacturing. An agriculture organization participating in recycling programs contributes to the circular economy, reducing the demand for new raw materials and conserving natural resources.

CHALLENGES IN AGRICULTURAL WASTE MANAGEMENT

Nutrient availability and soil cycling

Practices like burning crops or disposing of animal manure without recycling can lead to nutrient losses and reduced soil fertility. As a consequence, farmers are forced to use synthetic fertilizers, which can contribute to environmental pollution and greenhouse gas emissions.

Sustainable practices that can help address this challenge are:

- Improve soil health with compost
- Protect the soil with mulch and green manure
- Increase soil fertility with the proper biomass following nutrient release rates
- Technologies for nutrient reuse

Anaerobic digestion systems are the most effective solution to the challenges of nutrient reuse in agricultural waste management. Bacteria break down animal manure and organic waste in controlled, oxygen-free environments to produce biogas and nutrient-rich digestate.

The biogas can be used as a renewable energy source, while the digestate can serve as a nutrient-rich crop fertilizer. This closed-loop system helps capture and recycle nutrients to improve crop growth, enhance soil health and function, and reduce carbon footprint in food and animal production.

Reducing contaminants for improved food safety

Improper disposal or inadequate agricultural waste treatments can contaminate soil, water sources, and food crops with pesticides, herbicides, heavy metals, pathogens, and chemical residues.

As these contaminants accumulate in the food chain, they pose health risks to consumers and livestock.

Reducing contaminants starts with integrated pest management (IPM) practices that encourage using natural predators and crop rotation to control pests and diseases, reducing the need for pesticides.

Additionally, farmers must monitor the quality and safety of agricultural waste to ensure that derived products comply with safety standards.

Mitigating environmental emissions

Agricultural waste, especially manure, emits large amounts of methane and nitrous oxide during decomposition and fermentation. Additionally, improper waste disposal can lead to water and air pollution.

It's another issue where anaerobic digestion and composting can help. Implementing best management practices is another fundamental approach to mitigating environmental emissions. It involves waste storage, handling, and application methods to reduce the release of pollutants into the environment.

TECHNOLOGICAL ADVANCES AND INNOVATIONS

Gone are the days when agro-industrial wastes were labeled as trash. Today, we know that the bioactive compounds in agricultural wastes are valuable resources for producing biofuels, enzymes, vitamins, antioxidants, animal feed, antibiotics, and various chemicals.

So, technological advances have been significantly transforming agricultural waste management for more efficient and sustainable practices. On the one hand, technology like remote sensing, GPS systems, and data analytics optimizes agricultural input usage and minimizes waste generation.

On the other hand, advancements in waste-to-energy technologies have opened new possibilities for agricultural waste management. Technology enables us to convert farming residues and byproducts into green energy and bio-based chemicals. Not only do these technologies provide a sustainable solution for managing waste, but they also contribute to sustainable development and a circular economy.

AGRICULTURAL WASTE REGULATIONS

Overall, agricultural waste regulations aim to balance economic development, agricultural productivity, and the protection of the environment. International organizations, such as the **Food and Agriculture Organization of the United Nations** (FAO) and the **World Health Organization** (WHO), are crucial in promoting sustainable agricultural waste management practices globally. Furthermore, international agreements, such as the Paris Agreement on climate change, emphasize the importance of reducing agricultural emissions.

In the US, the **Environmental Protection Agency** (EPA) sets guidelines and standards in this field. States also play a significant role in regulating agricultural waste. Each state may have specific laws tailored to address unique farming practices and local environmental concerns.

State departments of agriculture and local environmental agencies oversee compliance with these regulations.

BENEFITS OF EFFECTIVE AGRICULTURAL WASTE MANAGEMENT

Farmers mitigate the risk of contaminating natural resources and preserve ecosystem health by reducing the release of harmful substances, such as pesticides, herbicides, and animal manure.

Recycling organic waste through composting or anaerobic digestion produces nutrient-rich fertilizers, protecting water quality and supporting sustainable food production at scale.

Farmers can earn more money and save on waste disposal costs by using waste for bioenergy or composting while improving soil health and crop productivity.

The proper waste treatment enhances food safety by minimizing exposure to harmful chemicals and pathogens.

Treating waste as a resource contributes to a more sustainable and resilient agricultural sector, long-term economic growth, and environmental protection.

- **Canada Agriculture Market Trends, Statistics, Growth, and Forecasts**

2020 | https://www.globalmonitor.us/product/canada-agriculture-market

Agriculture has always been of great importance for Canada, as feeding the world's largest population is not an easy task. The Canada government has been supporting the agriculture industry with a number of policies, trying to stabilise the output and seeking ways to ensure the sector is growing healthily and sustainably. The Canada federal government has been highly supportive of agriculture for decades, and there is broad political consensus as to the need for land, labour and tax reform to help the sector reach its potential.

Due to supportive policies, the agriculture sector's performance has been improving steadily in recent years. Canada keeps its first rank in the world in terms of farming output, producing large quantities of rice, wheat, cotton, meat, poultry, eggs and fishery products. The new strategy calls for more efforts to ensure the supply of key farm products, promoting the supply-side structural reform and, more importantly, enhancing environmental protection as well as pollution prevention and waste treatment.

Despite the rapid development of Canada's agriculture sector, problems emerge in relation to a variety of aspects, including the shrinking arable land, the deteriorating ecological status of environment due to the heavy use of fertilisers and pesticides, and the issue of food security. There is also much room to improve in terms of increasing the use of machinery and advanced technologies in the agriculture sector.

The country has made efforts to integrate new agricultural technologies to improve the sector's efficiency and increase land productivity. The high costs and low profits of agricultural production are the major internal inhibitors of Canada's agriculture sector. They are also the primary factor restricting the growth of farmers' income and leading to shrinking of the labour force in agriculture. Food safety has been a top concern for Canada consumers, especially concerning farm produce such as grains, meat, vegetables and seafood. Recent scandals have somewhat dampened consumers' confidence in food safety, and in response, the government has introduced regulations to improve food safety and strengthen quality monitoring. The increasing demand for high-quality agricultural products versus their limited supply ultimately results in increased imports. Some major product categories, including soybeans and dairy foods, have been heavily dependent on imports for many years. Other inhibitors to sector's growth include the ageing workforce with a low level of education and the underdeveloped rural financial services system.

The government has adopted a number of multi-year policies, such as a pledge to double farmer incomes and become self-sufficient in pulses over an unspecified short-term period. However, reform needs to go much deeper, especially considering the fact that in the years to 2050, agriculture is expected to provide livelihoods for about half the rural population, despite ongoing urbanisation in the country. Most farmers are engaged in low-scale subsistence farming and have a hard time accessing credit and paying it back. Therefore poverty and crop holiday years, as well as abandoning farming, or even committing suicide, is widespread among farmers in the country.

Canada has taken economic growth seriously and needs to feed its whetted appetite. Canada's agriculture sector provides livelihoods to households in rural areas. Together with forestry and fisheries, it is one of the largest contributors to Canada's GDP.

The Canada government has for decades actively supported the agriculture sector through mechanisms such as fertiliser subsidies, and relaxed lending conditions, amongst others, allowing farmers to have a fair estimation of their revenues and plan for the next agricultural season accordingly. Through a network of public institutions and various programmes and schemes, Canada's federal and regional authorities are trying to protect agricultural producers and boost production. A number of policy measures have been taken to address two major factors – soil and water – that are critical to improving agricultural output.

- **Global Sustainable Agriculture Market**

Feb 2023 | https://www.skyquestt.com/report/sustainable-agriculture-market

Global Sustainable Agriculture Market Insights

Global Sustainable Agriculture Market size was valued at USD 12.09 billion in 2021 and is poised to grow from USD 13.32 billion in 2022 to USD 28.91 billion by 2030, growing at a CAGR of 10.17% in the forecast period (2023-2030).

A farming practice known as sustainable agriculture puts an emphasis on supplying the needs of the present generation without jeopardizing the capacity of future generations to do the same. The goal of sustainable agriculture is to create a system that is environmentally, socially, and economically sustainable. This involves using farming practices that are environmentally friendly, such as minimizing the use of synthetic pesticides and fertilizers, reducing soil erosion and water usage, and promoting biodiversity. It also involves using farming methods that are socially responsible, such as promoting fair labor practices and working to reduce food waste and food insecurity. In addition, it focuses on the economic sustainability of the farm and the community it serves, through practices such as promoting local food systems, creating alternative income streams, and supporting rural development. Overall, sustainable agriculture is a holistic approach to farming that takes into account the interconnectedness of the environment, society, and the economy. It is aimed at creating a more resilient, equitable and sustainable food system for both present and future generations.

The global sustainable agriculture market is expected to see strong growth in the coming years, driven by a growing demand for sustainably produced food, increasing government support for these initiatives, and technological advancements in these practices. One of the key drivers of the market is increasing consumer demand for sustainably produced food. Consumers are becoming more aware of the environmental and social impact of their food choices, and are increasingly seeking out food that is produced using these practices. This has created a growing market for sustainably produced food, which is in turn driving the growth of the market.

Governments around the world are also playing a key role in driving the growth of the market. Many governments have launched initiatives to promote sustainable agriculture practices, such as the US Department of Agriculture's Agriculture and Food Research Initiative (AFRI) and the European Union's Common Agricultural Policy. These initiatives provide funding and support for farmers and researchers to develop and implement these practices. In addition to consumer demand and government support, technological advancements in these practices are also driving the growth of the market. New technologies such as precision agriculture, vertical farming, and biotechnology are allowing farmers to produce more food with fewer resources, while also reducing the environmental impact of agriculture.

One of the biggest challenges is the cost of implementing sustainable agriculture practices. Many sustainable agriculture practices require a significant upfront investment, and farmers may not have the resources to make these investments. In addition, these practices can sometimes result in lower yields, which can be a barrier to adoption. Despite these challenges, the global market is expected to see strong growth in the coming years. The market is expected to be driven by factors such as increasing consumer demand for

sustainably produced food, government support for sustainable agriculture initiatives, and technological advancements in these practices.

Global Sustainable Agriculture Market Segmental Analysis

Global sustainable agriculture market is segmented on the basis of product type, and region. By product type, the market is segmented seeds and traits, biopesticides, biostimulants, and others. By farming system, market is segmented into organic farming, conservation agriculture, integrated pest management (IPM), and precision agriculture. By region, the market is segmented into North America, Europe, Asia Pacific, Middle East and Africa, and Latin America.

Analysis by Product Type

The seeds and traits are the largest segments in the global sustainable agriculture market. The seeds and traits segment includes genetically modified (GM) seeds that have been developed to resist pests, diseases, and drought, and to increase crop yields. GM seeds also help to reduce the use of harmful pesticides and herbicides, which makes them more environmentally friendly. In addition, the use of GM seeds can help to increase food production and food security. The demand for GM seeds is expected to increase due to the growing population, rising demand for food, and shrinking arable land.

In terms of the fastest-growing segment, the biostimulants segment has been experiencing significant growth in recent years. The Biostimulants segment includes substances that enhance plant growth and nutrient uptake, such as humic acid, seaweed extracts, and beneficial microbes. Biostimulants help to improve crop yields and enhance soil health, which makes them more sustainable. In addition, biostimulants can be used in combination with other sustainable agriculture practices, such as organic farming and conservation agriculture, to further enhance their benefits. The demand for biostimulants is expected to increase due to their ability to improve crop yields and enhance soil health.

Analysis by Farming System

Precision agriculture is the largest segment in the global sustainable agriculture market. The Precision Agriculture segment includes products and technologies that use precision data and analytics to optimize crop yields, reduce waste, and improve resource efficiency. Products in this segment include precision irrigation systems, GPS-guided tractors, and drones for crop monitoring.

Organic farming is the fastest-growing segment in the global sustainable agriculture market. The Organic Farming segment includes agricultural biotechnology products and technologies that are specifically designed for use in organic farming systems, which prioritize sustainable and environmentally friendly practices. Products in this segment include biological pest control agents, natural fertilizers and soil conditioners, and non-GMO seeds.

Global Sustainable Agriculture Market Regional Insights

North America is a significant market for sustainable agriculture, with the United States being the largest market in the region. The United States is the largest market for sustainable agriculture in the region, with increasing consumer demand for sustainably produced food driving the growth of the market. The adoption of these practices is also being supported by government initiatives such as the Agriculture and Food Research Initiative (AFRI) and the Sustainable Agriculture Research and Education (SARE) program. In addition to the United States, Canada is also a significant market in the region, with a growing focus on sustainable agriculture practices and increasing government support for these initiatives. The adoption of these practices in Canada is being driven by a growing awareness of the importance of sustainable agriculture, as well as increasing demand for sustainably produced food from consumers. The North American market is being driven by factors such as increasing consumer demand for sustainably produced food, government support for these initiatives, and technological advancements in these practices. The

region is expected to continue to see strong growth in the adoption of sustainable agriculture practices over the coming years.

The Asia-Pacific region is expected to see the fastest growth in the sustainable agriculture market. The Asia-Pacific market is being driven by factors such as increasing demand for food due to a growing population, increasing government support for these initiatives, and a growing awareness of the importance of sustainable agriculture. Countries such as India and China are expected to be major growth markets in the region. In India, the government has launched several initiatives to promote these practices, such as the Paramparagat Krishi Vikas Yojana (PKVY), which aims to promote organic farming in the country. In addition, increasing consumer demand for sustainably produced food is driving the growth of the sustainable agriculture market in India. In China, the government has launched the "Action Plan for Zero Growth in Fertilizer and Pesticide Use in China by 2020", which aims to reduce the use of fertilizers and pesticides in agriculture and promote these practices. Increasing consumer demand for organic food is also driving the growth of the market in China. Other countries in the Asia-Pacific region, such as Australia and Japan, are also significant markets for sustainable agriculture, with increasing government support for these initiatives and a growing awareness of the importance of sustainable agriculture driving the growth of the market.

Drivers

Increasing demand for food

As the world's population continues to grow, the demand for food is also increasing. Sustainable agriculture practices help to increase yields and ensure that food is produced in a more efficient and environmentally friendly way.

Need to reduce environmental impact

Agriculture is a major source of greenhouse gas emissions, water pollution, and other environmental problems. Sustainable agriculture practices can help to reduce the environmental impact of agriculture, making it more sustainable over the long term.

Regulatory support

Governments around the world are increasingly supporting sustainable agriculture practices through various policies and initiatives. This is helping to drive the adoption of these practices among farmers and other stakeholders.

Restraints

High costs

Sustainable agriculture practices often require significant investments in new technology, infrastructure, and training. This can make it difficult for some farmers, particularly small-scale farmers, to adopt these practices.

Lack of awareness and education

There is still a lack of awareness and education about sustainable agriculture practices among farmers, policymakers, and other stakeholders. This can make it difficult to drive the adoption of these practices across the industry.

Limited availability of sustainable inputs

There is currently limited availability of sustainable inputs, such as seeds and fertilizers, which can make it difficult for farmers to adopt sustainable agriculture practices.

Limited access to financing

Sustainable agriculture practices often require significant investments, which can be difficult for some farmers to access. Limited access to financing can make it difficult for farmers to adopt these practices.

Global Sustainable Agriculture Market Competitive Landscape

The global sustainable agriculture market is highly competitive, with numerous players operating in the industry. These companies operate across the entire value chain of sustainable agriculture, including the development and production of sustainable crop protection products, seeds, fertilizers, irrigation systems, and other agricultural inputs, as well as digital tools and precision agriculture technology. Many of these companies also have a strong focus on sustainable agriculture research and development and are investing heavily in the development of new and innovative solutions. The global market is shaped by a range of factors, including regulatory frameworks, shifting consumer preferences, and advancements in technology. In order to remain competitive, companies in the market must constantly innovate and adapt to changing market conditions, while also maintaining a strong focus on sustainability and environmental responsibility. Overall, the global market is expected to continue to grow and evolve in the coming years, presenting significant opportunities for companies that are able to effectively navigate this rapidly changing landscape.

Top Player's Company Profiles

- Archer Daniels Midland Company
- BASF SE
- Bayer AG
- Bunge Limited
- Cargill, Incorporated
- Corteva Agriscience
- Danone
- General Mills, Inc.
- Kellogg Company
- Kraft Heinz Company
- Mars, Incorporated
- Monsanto Company
- Nestlé S.A.
- PepsiCo, Inc.
- Syngenta AG
- The Coca-Cola Company
- The Hershey Company
- Unilever
- Yara International ASA
- Zoetis Inc.

Recent Developments

In November 2021, BASF announced that it had developed a new bio-based herbicide, which is made from 100% renewable resources. The herbicide is designed to provide an alternative to conventional herbicides, which can have negative environmental impacts.

In September 2021, Syngenta announced that it had received approval from the European Union for a new fungicide, which is designed to protect crops against a range of fungal diseases. The fungicide is based on a naturally occurring molecule and is considered to be more sustainable than conventional fungicides.

In August 2021, Corteva Agriscience announced that it had launched a new line of seed products that are designed to improve soil health and promote sustainable agriculture practices. The seed products are designed to improve nutrient availability and reduce erosion, among other benefits.

In July 2021, Monsanto announced that it had invested in a new startup, called Pivot Bio, which is developing a new microbial product that can be used to replace synthetic nitrogen fertilizers. The product is designed to help farmers reduce their environmental impact and increase their yields.

In May 2021, The Mosaic Company announced that it had entered into a partnership with AgBiome, a biotechnology company that is developing sustainable crop protection solutions. The partnership will focus on developing new microbial products that can help farmers reduce their use of synthetic pesticides.

Global Sustainable Agriculture Key Market Trends

Increasing consumer demand for sustainable and organic food products: Consumers are becoming more aware of the environmental impact of conventional agriculture, and are increasingly looking for sustainable and organic food products. This is driving demand for sustainable agriculture practices and products.

Growing adoption of precision agriculture techniques: Precision agriculture techniques, such as GPS mapping, drone technology, and soil sensors, are becoming more widely adopted by farmers. These techniques allow farmers to manage their crops and resources, which can result in higher yields and more sustainable practices.

Rising popularity of regenerative agriculture: Regenerative agriculture is a holistic approach to farming that focuses on building soil health, improving biodiversity, and sequestering carbon. This approach is gaining popularity among farmers and consumers as a way to mitigate the environmental impact of agriculture.

Increasing investment in sustainable agriculture: Governments and private companies are investing more in sustainable agriculture, which is driving innovation and growth in the market. For example, the EU's Common Agricultural Policy includes measures to promote sustainable agriculture, while private companies are investing in research and development of these products.

Integration of technology with sustainable agriculture practices: Technology is being increasingly integrated with sustainable agriculture practices, allowing for more efficient and effective management of crops and resources. For example, artificial intelligence and machine learning can be used to analyze data and optimize crop management.

Global Sustainable Agriculture Market SkyQuest Analysis

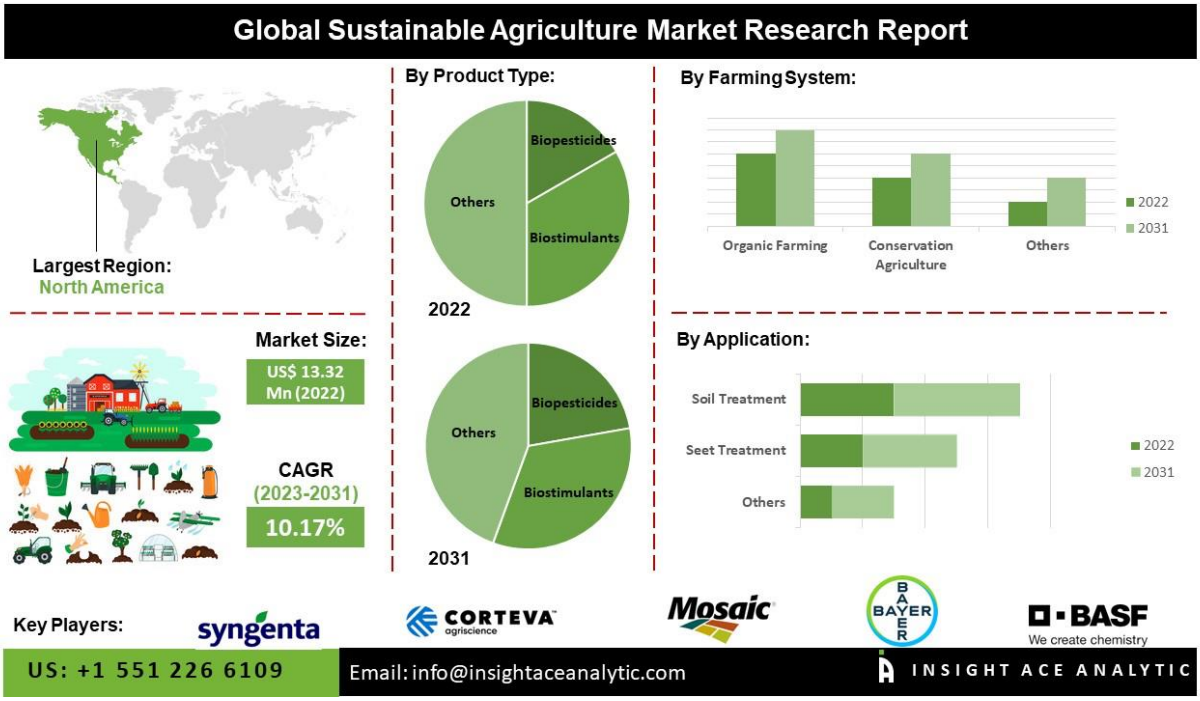
According to our sustainable agriculture market analysis, the global market is a growing market that is expected to see significant growth in the coming years. North America is expected to be the largest market, driven by increasing government support for sustainable agriculture initiatives and a growing demand for sustainably produced food. Asia Pacific is also expected to see significant growth, driven by a growing population and increasing demand for food. However, the market also faces some challenges. One of the biggest challenges is the cost of implementing these practices. Many such practices require a significant upfront investment, and farmers may not have the resources to make these investments. In addition, these practices can sometimes result in lower yields, which can be a barrier to adoption. Overall, the global sustainable agriculture market is expected to see strong growth in the coming years, driven by factors such as increasing consumer demand for sustainably produced food, government support for these initiatives, and technological advancements in these practices. However, the market also faces some challenges and will require continued innovation and investment to reach its full potential.

► Sustainable Agriculture Market

Aug 2023 | https://www.insightaceanalytic.com/report/sustainable-agriculture-market/1661

The Global Sustainable Agriculture Market size is valued at 13.32 billion in 2022 and is predicted to reach 31.35 billion by the year 2031 at a 10.17% CAGR during the forecast period for 2023-2031.

Sustaining agricultural production depends on the quality and availability of natural resources like soil and water. Agricultural expansion may be supported by encouraging the conservation and sustainable use of these precious natural resources through suitable area-specific measures. Sustainable agriculture systems are those that are financially viable and meet society's demand for safe and healthy food while preserving or enhancing environmental resources and the quality of the environment for future years.



In addition to the extensive use of no-till agriculture, crop rotation, animal rotations, and recycling techniques, rising worries about global environmental disturbance are predicted to drive category growth over the forecast period. Utilizing low-cost, locally sourced resources efficiently integrates with sustainable farming philosophy to provide healthy soil, nutritious food, pure water, and clean air. By providing nutrients and increasing pest and disease resistance, this long-term holistic approach raises the quality of the soil.

However, it is commonly recognized that weather and climate change directly impact agricultural productivity. Under normal conditions, the climate during the growing season determines how well crops develop, grow, use water, and produce. Crop productivity can be severely hampered by even a slight departure from the usual. Global warming has affected the hydrological cycle, which impacts India's rainfall volume and frequency. India is facing issues with agricultural sustainability, an increase in extreme events, and annual large-scale droughts that affect around one-third of the country on average. Given that most arable land lacks irrigation infrastructure, water availability becomes the most important aspect of agriculture.

Recent Developments:

In Sept 2022, Bayer publicised a regenerative farming partnership with Perdue AgriBusiness, strived at large-scale carbon emission reductions and created a model for a more sustainable food value chain spanning across Perdue's entire grain network. Through the collaboration, Bayer and Perdue AgriBusiness, the international agricultural products and services business of Perdue Farms, are developing further opportunities to assist support farmers on their regenerative agriculture journey, helping their land and helping them produce more environmentally friendly foods and ingredients for companies and consumers.

In November 2021, BASF introduced the latest bio-based herbicide, made from completely renewable resources. This herbicide is used as an alternative to conventional herbicides.

Competitive Landscape:

Some of the Global Sustainable Agriculture market players are:

- BASF SE (Germany)
- Corteva Agriscience (US)
- The Mosaic Company (US)
- Yara International (US)
- Monsanto Company (US)
- Pioneer Hi-Bred International (US)
- John Deere (US)
- AGCO Corporation (US)
- Trimble Inc. (US)
- Deere & Company (US)
- Archer Daniels Midland (US)
- Cargill (US)
- Groupe Limagrain (France)
- KWS SAAT (Germany)
- Netafim (Israel)
- Irritec (Italy)
- UPL Limited (India)
- Godrej Agrovet (India)
- China National Chemical Corporation (China)
- KUBOTA Corporation (Japan)
- Thai Union Group PCL (Thailand)

Market Segmentation:

The Global Sustainable Agriculture market is segmented on the basis of product type, farming system, Formulation, Crop type and Application. On the basis of product type, the market is segregated into Seeds and traits, biopesticides, biostimulants, and others. The farming system segment includes Organic farming, conservation agriculture, integrated pest management (IPM), and precision agriculture. Based on the formulation, the market is segmented into liquid and dry and Crop type segment contains Cereals & Grains, Oilseeds & Pulses, Fruits & Vegetables, amd Other Crop Types. The last segment is Application which includes Seed Treatment, Soil Treatment, Foliar spray, Other.

Based On Product Type, The Seeds And Traits Segment Is A Significant Contributor To The Global Sustainable Agriculture Market

The seeds and traits category will hold a major global Sustainable Agriculture market share in 2022. Genetically modified (GM) seeds were created in this sector to boost crop yields and resist pests, illnesses,

and drought. Using toxic pesticides and herbicides may be reduced if GM seeds include good features like enhanced resistance to problems and illnesses. This helps farmers' expenses by making them less expensive and more environmentally friendly.

Precision Agriculture Segment Witnessed Growth At A Rapid Rate

The market for sustainable agriculture will be dominated by precision agriculture. It had the most significant market share in 2022. This market category consists of goods and services that maximize crop yields, cut waste, and increase resource efficiency through the use of precision data and analytics. Precision irrigation systems, GPS-guided tractors, and drones for agricultural monitoring are a few of the goods in this market category. Canada is another key market in the area for precision agriculture, in addition to the United States.

In The Region, The North America Global Sustainable Agriculture Market Holds Significant Revenue Share

The United States is the region's largest market and is a significant sustainable agriculture market. The market for sustainable agriculture in the US is expanding as a result of rising customer demand for food that has been produced sustainably. Precision farming is expected to surpass other innovations to become the most significant trend in agriculture by the end of 2030. Precision agriculture practices allow farmers to reduce their environmental effect while increasing yields and profitability. Besides, the market for sustainable agriculture is expanding significantly, with the Asia-Pacific area predicted to grow the fastest over the next few years. Smallholder farmers grow more than 82% of the food that is consumed in sub-Saharan Africa and Asia. As a result, the development of sustainable agricultural practices offers a chance to enhance these farmers' lives while also advancing the sustainability of food production.

Report Attribute	Specifications
Market size value in 2022	USD 13.32 Bn
Revenue forecast in 2031	USD 31.35 Bn
Growth rate CAGR	CAGR of 10.17 % from 2023 to 2031
Quantitative units	Representation of revenue in US$ Billion, and CAGR from 2023 to 2031
Historic Year	2019 to 2022
Forecast Year	2023-2031
Report coverage	The forecast of revenue, the position of the company, the competitive market statistics, growth prospects, and trends
Segments covered	Product Type, Farming System, Crop type, Formulation, And Application
Regional scope	North America; Europe; Asia Pacific; Latin America; Middle East & Africa
Country scope	U.S.; Canada; U.K.; Germany; China; India; Japan; Brazil; Mexico; The UK; France; Italy; Spain; China; Japan; India; South Korea; Southeast Asia; South Korea; Southeast Asia
Competitive Landscape	BASF SE (Germany), Corteva Agriscience (US), The Mosaic Company (US), Yara International (US), Dow AgroSciences (US), Monsanto Company (US), Pioneer Hi-Bred International (US), John Deere (US), AGCO Corporation (US), Trimble Inc. (US), Deere & Company (US), Archer Daniels Midland (US), Cargill (US), DuPont (US), Groupe Limagrain (France), KWS SAAT (Germany), Netafim (Israel), Irritec (Italy), UPL Limited (India), Godrej Agrovet (India), China National Chemical Corporation (China), KUBOTA Corporation (Japan), Thai Union Group PCL (Thailand).

► Agriculture Top Trends to Watch For in 2023

Jan 2023 | https://www.icl-group.com/blog/agriculture-top-trends-to-watch-for-in-2023/

Agriculture in the 21st century faces unique challenges. From a population projected to grow by over a third by 2050 to a changing climate and the need to get to net zero emissions in the same time frame, there is lots of work to be done to achieve food security for the future.

In these unprecedented times, it's easy to be overcome with uncertainty. Hadar Sutovsky, Vice President of External Innovation at ICL, notes a few technological innovation areas within the agri-food industry that can make it possible to push agrifood systems towards sustainability and resilience, and help provide sufficient, healthy, and sustainable food.

- Alternative Proteins
- Food waste mitigation
- Animal health
- Aquaculture
- Ag Biotech
- Carbon sequestration
- Digital Agriculture as well as automation & robotics
- Vertical & indoor farming

These key sectors will continue to be active with innovation in 2023. As one of the global leaders creating impactful solutions for sustainability challenges in the global food, agriculture, and industrial markets, we're sharing our expectations for innovation in precision agriculture in 2023. The areas that we anticipate to be ones to watch for are automation & robotics, precision agriculture, digital agriculture, and sustainability practices.

The Intersection of Robotics & Automation and Agriculture

Talking about robotics and automation in agriculture Hadar tells us *"… they are promising technologies for enhancing agriculture's efficiency and productivity. Farmers have started to experiment with autonomous systems that automate or augment operations such as pruning, thinning, and harvesting, as well as mowing, spraying, and weed removal. In the fruit tree industry, for example, workers riding robotic platforms can be up to twice as efficient as workers using traditional ladders.*

Advances in sensors, artificial intelligence, and control systems allow for optimal implementation of integrated pest and disease management. Overarchingly, these innovations can help reduce labor costs, ensure optimized resource use, and enhance efficiency on the farm. This supports a key goal of growing more food with fewer inputs."

Digital Agriculture

Digital agriculture solutions are rapidly changing the agriculture industry through the use of modern machinery and computerized tools. Decision-making can be more efficient with data from digital agriculture solutions, improving overall farm productivity. Digital agriculture will be an important part of agtech trends in 2023.

In digital agriculture, unmanned aerial vehicles (UAVs) are used to optimize operational efficiency, crop production, and crop field monitoring. UAV technology includes remote sensing and imaging to detect soil variation, irrigation problems, and fungal infestations.

The agriculture UAV market is projected to go from $0.88B in 2020 to $5.89B by 2030, fueled by new technologies and additional venture funding. Drone-related government regulations are also expected to rise. UAVs are also used in other areas of agriculture. For livestock monitoring, UAVs can track cattle and sheep in pastures. While it might be a challenging flight environment, UAVs can be used in smart greenhouses for crop scouting and inventory, inspecting structures, and even applying shade compounds. And for precision fish farming, drones have a place in efficient data collection on water quality and temperature, fish behavior, and wave velocity – with much lower labor costs.

Transparent Sustainability Practices

According to the United Nations (UN), global population growth to 10 billion is expected by the end of this century. The need to produce more high-quality food on less land in a sustainable way is imminent. The UN World Commission on Environment and Development defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

In 2023, agriculture sustainability trends will include a focus on transparency, circular economies, and reducing greenhouse gas emissions.

There will be a greater desire for transparency in sustainability practices. More and more, consumers care about where their goods come from and the processes used to create, supply, and transport them. Transparency will be increasingly of interest throughout the supply chain.

Circular economies and circular agriculture will become more common. With a focus on using minimal external inputs, circular agriculture can reduce agriculture's footprint and resource requirements, ultimately addressing greenhouse gas emissions. Reusing and recycling materials is an important part of this practice and is typically used in smallholder farming.

Advanced technologies will play an important role in sustainability in agriculture. PwC estimates that artificial intelligence (AI) could reduce worldwide GHG emissions by 4% in 2030 through the agriculture, water, energy, and transport sectors.

- **Global Farmer Insights 2022**

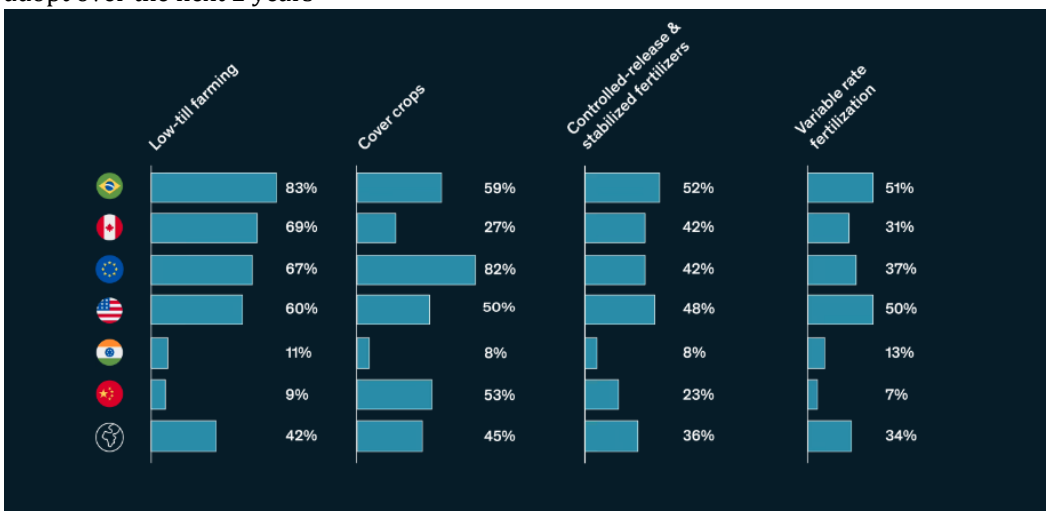
2022 | https://globalfarmerinsights2022.mckinsey.com/#d04

McKinsey has surveyed 5,500+ farmers across the globe to better understand their mindsets and behaviors towards key topics shaping the future of agriculture.

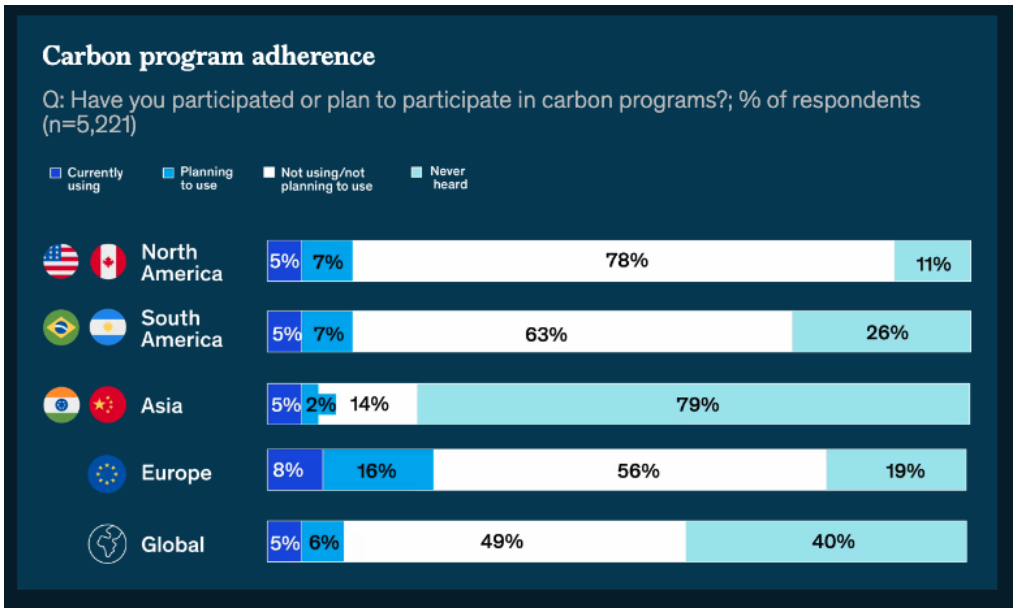


Global adoption of sustainable practices is still <50%. Brazil is ahead, followed by Europe; only 5% of farmers participate in carbon programs with Canada having the highest participation.

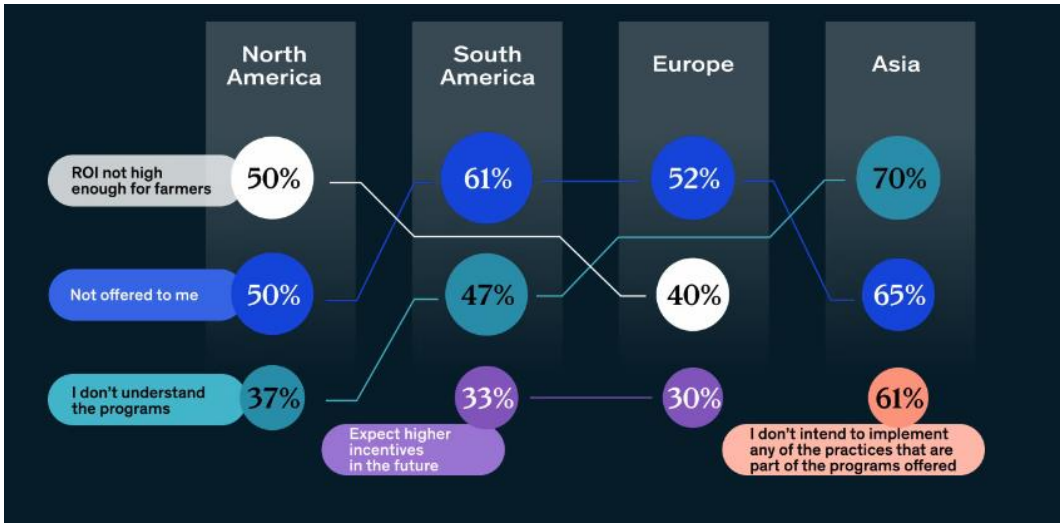
Sustainability practices adoption and willingness to adopt % respondents currently adopting or willing to adopt over the next 2 years



Carbon program adherence



Top 3 challenges to participating in carbon programs



► **Agriculture's connected future: How technology can yield new growth**

Oct 2020 | https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth

One of the oldest industries must embrace a digital, connectivity-fueled transformation in order to overcome increasing demand and several disruptive forces.

The agriculture industry has radically transformed over the past 50 years. Advances in machinery have expanded the scale, speed, and productivity of farm equipment, leading to more efficient cultivation of more land. Seed, irrigation, and fertilizers also have vastly improved, helping farmers increase yields. Now, agriculture is in the early days of yet another revolution, at the heart of which lie data and connectivity. Artificial intelligence, analytics, connected sensors, and other emerging technologies could further increase yields, improve the efficiency of water and other inputs, and build sustainability and resilience across crop cultivation and animal husbandry.

Without a solid connectivity infrastructure, however, none of this is possible. If connectivity is implemented successfully in agriculture, the industry could tack on $500 billion in additional value to the global gross domestic product by 2030, according to our research. This would amount to a 7 to 9 percent improvement from its expected total and would alleviate much of the present pressure on farmers. It is one of just seven sectors that, fueled by advanced connectivity, will contribute $2 trillion to $3 trillion in additional value to global GDP over the next decade, according to research by the McKinsey Center for Advanced Connectivity and the McKinsey Global Institute (MGI) (see sidebar "The future of connectivity").

Demand for food is growing at the same time the supply side faces constraints in land and farming inputs. The world's population is on track to reach 9.7 billion by 2050,[1] requiring a corresponding 70 percent increase in calories available for consumption, even as the cost of the inputs needed to generate those calories is rising.[2] By 2030, the water supply will fall 40 percent short of meeting global water needs,[3] and rising energy, labor, and nutrient costs are already pressuring profit margins. About one-quarter of arable land is degraded and needs significant restoration before it can again sustain crops at scale.[4] And then there are increasing environmental pressures, such as climate change and the economic impact of catastrophic weather events, and social pressures, including the push for more ethical and sustainable farm practices, such as higher standards for farm-animal welfare and reduced use of chemicals and water.

To address these forces poised to further roil the industry, agriculture must embrace a digital transformation enabled by connectivity. Yet agriculture remains less digitized compared with many other industries globally. Past advances were mostly mechanical, in the form of more powerful and efficient machinery, and genetic, in the form of more productive seed and fertilizers. Now much more sophisticated, digital tools are needed to deliver the next productivity leap. Some already exist to help farmers more efficiently and sustainably use resources, while more advanced ones are in development. These new technologies can upgrade decision making, allowing better risk and variability management to optimize yields and improve economics. Deployed in animal husbandry, they can enhance the well-being of livestock, addressing the growing concerns over animal welfare.

Demand for food is growing at the same time the supply side faces constraints in land and farming inputs.

But the industry confronts two significant obstacles. Some regions lack the necessary connectivity infrastructure, making development of it paramount. In regions that already have a connectivity infrastructure, farms have been slow to deploy digital tools because their impact has not been sufficiently proven.

The COVID-19 crisis has further intensified other challenges agriculture faces in five areas: efficiency, resilience, digitization, agility, and sustainability. Lower sales volumes have pressured margins, exacerbating the need for farmers to contain costs further. Gridlocked global supply chains have highlighted the importance of having more local providers, which could increase the resilience of smaller farms. In this global pandemic, heavy reliance on manual labor has further affected farms whose workforces face mobility restrictions. Additionally, significant environmental benefits from decreased travel and consumption during the crisis are likely to drive a desire for more local, sustainable sourcing, requiring producers to adjust long-standing practices. In short, the crisis has accentuated the necessity of more widespread digitization and automation, while suddenly shifting demand and sales channels have underscored the value of agile adaptation.

Current connectivity in agriculture

In recent years, many farmers have begun to consult data about essential variables like soil, crops, livestock, and weather. Yet few if any have had access to advanced digital tools that would help to turn these data into valuable, actionable insights. In less-developed regions, almost all farmwork is manual, involving little or no advanced connectivity or equipment.

Even in the United States, a pioneer country in connectivity, only about one-quarter of farms currently use any connected equipment or devices to access data, and that technology isn't exactly state-of-the-art, running on 2G or 3G networks that telcos plan to dismantle or on very low-band IoT networks that are complicated and expensive to set up. In either case, those networks can support only a limited number of devices and lack the performance for real-time data transfer, which is essential to unlock the value of more advanced and complex use cases.

Nonetheless, current IoT technologies running on 3G and 4G cellular networks are in many cases sufficient to enable simpler use cases, such as advanced monitoring of crops and livestock. In the past, however, the cost of hardware was high, so the business case for implementing IoT in farming did not hold up. Today, device and hardware costs are dropping rapidly, and several providers now offer solutions at a price we believe will deliver a return in the first year of investment.

These simpler tools are not enough, though, to unlock all the potential value that connectivity holds for agriculture. To attain that, the industry must make full use of digital applications and analytics, which will require low latency, high bandwidth, high resiliency, and support for a density of devices offered by advanced and frontier connectivity technologies like LPWAN, 5G, and LEO satellites (Exhibit 1).

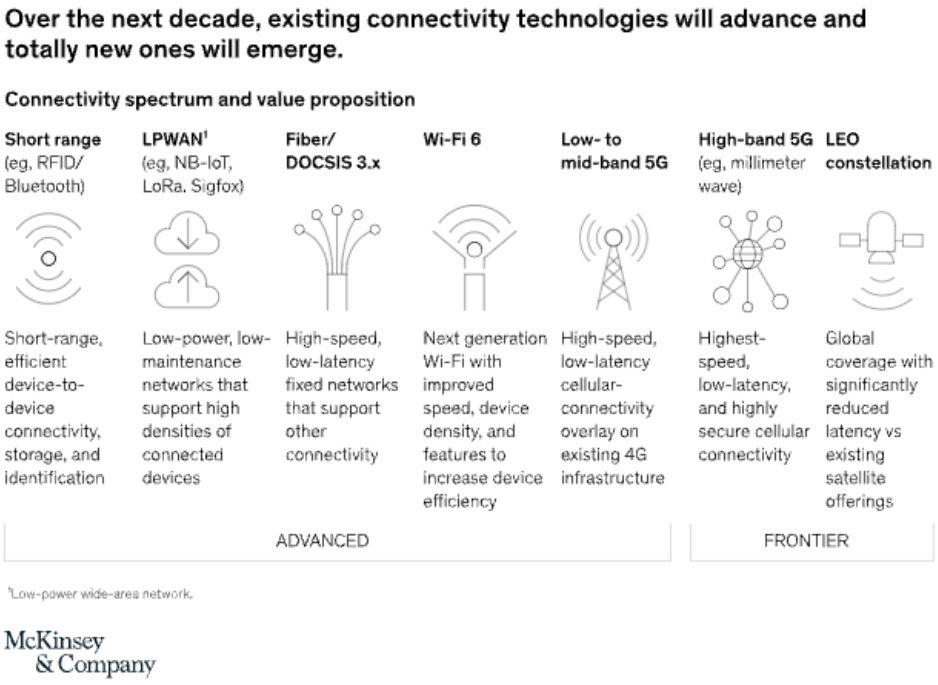


Exhibit 1

The challenge the industry is facing is thus twofold: infrastructure must be developed to enable the use of connectivity in farming, and where connectivity already exists, strong business cases must be made in order for solutions to be adopted. The good news is that connectivity coverage is increasing almost everywhere. By 2030, we expect advanced connectivity infrastructure of some type to cover roughly 80 percent of the world's rural areas; the notable exception is Africa, where only a quarter of its area will be covered. The key, then, is to develop more—and more effective—digital tools for the industry and to foster widespread adoption of them.

As connectivity increasingly takes hold, these tools will enable new capabilities in agriculture:

Massive Internet of Things. Low-power networks and cheaper sensors will set the stage for the IoT to scale up, enabling such use cases as precision irrigation of field crops, monitoring of large herds of livestock, and tracking of the use and performance of remote buildings and large fleets of machinery.

Mission-critical services. Ultralow latency and improved stability of connections will foster confidence to run applications that demand absolute reliability and responsiveness, such as operating autonomous machinery and drones.

Near-global coverage. If LEO satellites attain their potential, they will enable even the most remote rural areas of the world to use extensive digitization, which will enhance global farming productivity.

Connectivity's potential for value creation

By the end of the decade, enhanced connectivity in agriculture could add more than $500 billion to global gross domestic product, a critical productivity improvement of 7 to 9 percent for the industry.[5] Much of that value, however, will require investments in connectivity that today are largely absent from agriculture. Other industries already use technologies like LPWAN, cloud computing, and cheaper, better sensors requiring minimal hardware, which can significantly reduce the necessary investment. We have analyzed five use cases—crop monitoring, livestock monitoring, building and equipment management, drone farming, and autonomous farming machinery—where enhanced connectivity is already in the early stages of being

used and is most likely to deliver the higher yields, lower costs, and greater resilience and sustainability that the industry needs to thrive in the 21st century (Exhibit 2).

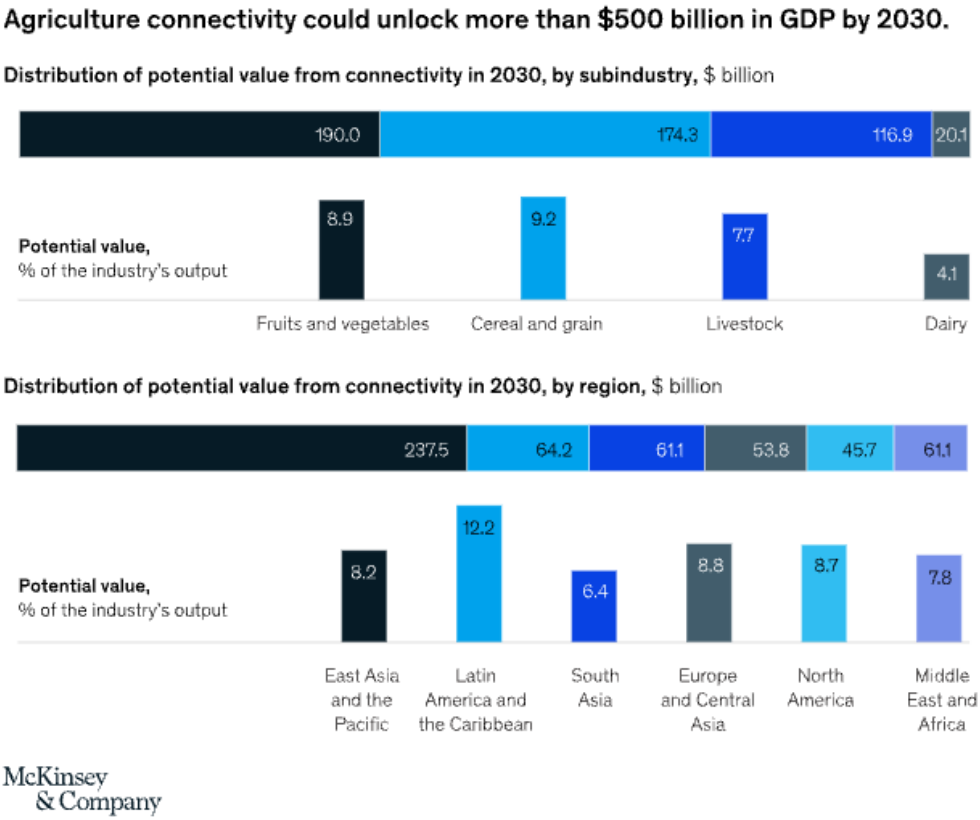


Exhibit 2

It's important to note that use cases do not apply equally across regions. For example, in North America, where yields are already fairly optimized, monitoring solutions do not have the same potential for value creation as in Asia or Africa, where there is much more room to improve productivity. Drones and autonomous machinery will deliver more impact to advanced markets, as technology will likely be more readily available there (Exhibit 3).

A number of advanced connectivity use cases have the potential to radically transform many aspects of farming by 2030.

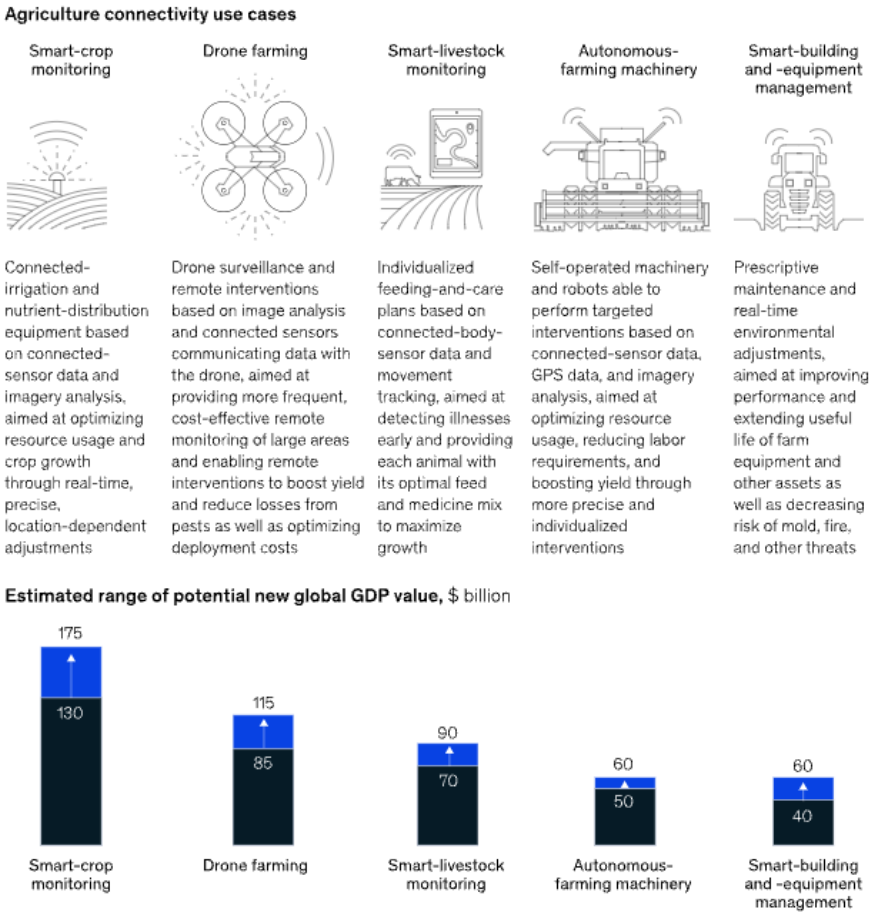


Exhibit 3

Potential value initially will accrue to large farms that have more investing power and better incentives to digitize. Connectivity promises easier surveying of large tracts, and the fixed costs of developing IoT solutions are more easily offset in large production facilities than on small family farms. Crops like cereals, grains, fruits, and vegetables will generate most of the value we identified, for similar reasons. Connectivity enables more use cases in these sectors than in meat and dairy, because of the large average size of farms, relatively higher player consolidation, and better applicability of connected technologies, as IoT networks are especially adapted to static monitoring of many variables. It's also interesting to note that Asia should garner about 60 percent of the total value simply because it produces the biggest volume of crops (see sidebar "About the use-case research").

Use case 1: Crop monitoring

Connectivity offers a variety of ways to improve the observation and care of crops. Integrating weather data, irrigation, nutrient, and other systems could improve resource use and boost yields by more accurately identifying and predicting deficiencies. For instance, sensors deployed to monitor soil conditions could communicate via LPWAN, directing sprinklers to adjust water and nutrient application. Sensors could also deliver imagery from remote corners of fields to assist farmers in making more informed and timely decisions and getting early warnings of problems like disease or pests.

Smart monitoring could also help farmers optimize the harvesting window. Monitoring crops for quality characteristics—say, sugar content and fruit color—could help farmers maximize the revenue from their crops.

Most IoT networks today cannot support imagery transfer between devices, let alone autonomous imagery analysis, nor can they support high enough device numbers and density to monitor large fields accurately. Narrowband Internet of Things (NB-IoT) and 5G promise to solve these bandwidth and connection-density issues. The use of more and smoother connections between soil, farm equipment, and farm managers could unlock $130 billion to $175 billion in value by 2030.

Use case 2: Livestock monitoring

Preventing disease outbreaks and spotting animals in distress are critical in large-scale livestock management, where most animals are raised in close quarters on a regimen that ensures they move easily through a highly automated processing system. Chips and body sensors that measure temperature, pulse, and blood pressure, among other indicators, could detect illnesses early, preventing herd infection and improving food quality. Farmers are already using ear-tag technology from providers such as Smartbow (part of Zoetis) to monitor cows' heat, health, and location, or technology from companies such as Allflex to implement comprehensive electronic tracing in case of disease outbreaks.

Similarly, environmental sensors could trigger automatic adjustments in ventilation or heating in barns, lessening distress and improving living conditions that increasingly concern consumers. Better monitoring of animal health and growth conditions could produce $70 billion to $90 billion in value by 2030.

Would you like to learn more about the McKinsey Center for Advanced Connectivity?

Use case 3: Building and equipment management

Chips and sensors to monitor and measure levels of silos and warehouses could trigger automated reordering, reducing inventory costs for farmers, many of whom are already using such systems from companies like Blue Level Technologies. Similar tools could also improve shelf life of inputs and reduce post-harvest losses by monitoring and automatically optimizing storage conditions. Monitoring conditions and usage of buildings and equipment also has the potential to reduce energy consumption. Computer vision and sensors attached to equipment and connected to predictive-maintenance systems could decrease repair costs and extend machinery and equipment life.

Such solutions could achieve $40 billion to $60 billion in cost savings by 2030.

Use case 4: Farming by drone

Agriculture has been using drones for some two decades, with farmers around the world relying on pioneers like Yamaha's RMAX remote-controlled helicopter to help with crop spraying. Now the next generation of drones is starting to impact the sector, with the ability to survey crops and herds over vast areas quickly and efficiently or as a relay system for ferrying real-time data to other connected equipment and installations. Drones also could use computer vision to analyze field conditions and deliver precise interventions like fertilizers, nutrients, and pesticides where crops most need them. Or they could plant seed in remote locations, lowering equipment and workforce costs. By reducing costs and improving yields, the use of drones could generate between $85 billion and $115 billion in value.

Use case 5: Autonomous farming machinery

More precise GPS controls paired with computer vision and sensors could advance the deployment of smart and autonomous farm machinery. Farmers could operate a variety of equipment on their field simultaneously and without human intervention, freeing up time and other resources. Autonomous machines are also more efficient and precise at working a field than human-operated ones, which could

generate fuel savings and higher yields. Increasing the autonomy of machinery through better connectivity could create $50 billion to $60 billion of additional value by 2030.

Additional sources of value

Connected technologies offer an additional, indirect benefit, the value of which is not included in the estimates given in these use cases. The global farming industry is highly fragmented, with most labor done by individual farm owners. Particularly in Asia and Africa, few farms employ outside workers. On such farms, the adoption of connectivity solutions should free significant time for farmers, which they can use to farm additional land for pay or to pursue work outside the industry.

We find the value of deploying advanced connectivity on these farms to achieve such labor efficiencies represents almost $120 billion, bringing the total value of enhanced connectivity from direct and indirect outcomes to more than $620 billion by 2030. The extent to which this value will be captured, however, relies largely on advanced connectivity coverage, which is expected to be fairly low, around 25 percent, in Africa and poorer parts of Asia and Latin America. Achieving the critical mass of adopters needed to make a business case for deploying advanced connectivity also will be more difficult in those regions, where farming is more fragmented than in North America and Europe.

Implications for the agricultural ecosystem

As the agriculture industry digitizes, new pockets of value will likely be unlocked. To date, input providers selling seed, nutrients, pesticides, and equipment have played a critical role in the data ecosystem because of their close ties with farmers, their own knowledge of agronomy, and their track record of innovation. For example, one of the world's largest fertilizer distributors now offers both fertilizing agents and software that analyzes field data to help farmers determine where to apply their fertilizers and in what quantity. Similarly, a large-equipment manufacturer is developing precision controls that make use of satellite imagery and vehicle-to-vehicle connections to improve the efficiency of field equipment.

Advanced connectivity does, however, give new players an opportunity to enter the space. For one thing, telcos and LPWAN providers have an essential role to play in installing the connectivity infrastructure needed to enable digital applications on farms. They could partner with public authorities and other agriculture players to develop public or private rural networks, capturing some of the new value in the process.

Agritech companies are another example of the new players coming into the agriculture sphere. They specialize in offering farmers innovative products that make use of technology and data to improve decision making and thereby increase yields and profits. Such agritech enterprises could proffer solutions and pricing models that reduce perceived risk for farmers—with, for example, subscription models that remove the initial investment burden and allow farmers to opt out at any time—likely leading to faster adoption of their products. An Italian agritech is doing this by offering to monitor irrigation and crop protection for wineries at a seasonal, per-acre fee inclusive of hardware installation, data collection and analysis, and decision support. Agritech also could partner with agribusinesses to develop solutions.

Still, much of this cannot happen until many rural areas get access to a high-speed broadband network. We envision three principal ways the necessary investment could take place to make this a reality:

Telco-driven deployment. Though the economics of high-bandwidth rural networks have generally been poor, telcos could benefit from a sharp increase in rural demand for their bandwidth as farmers embrace advanced applications and integrated solutions.

Provider-driven deployment. Input providers, with their existing industry knowledge and relationships, are probably best positioned to take the lead in connectivity-related investment. They could partner with telcos

or LPWAN businesses to develop rural connectivity networks and then offer farmers business models integrating connected technology and product and decision support.

Farmer-driven deployment. Farm owners, alone or in tandem with LPWAN groups or telcos, could also drive investment. This would require farmers to develop the knowledge and skills to gather and analyze data locally, rather than through third parties, which is no small hurdle. But farmers would retain more control over data.

How to do it

Regardless of which group drives the necessary investment for connectivity in agriculture, no single entity will be able to go it alone. All of these advances will require the industry's main actors to embrace collaboration as an essential aspect of doing business. Going forward, winners in delivering connectivity to agriculture will need deep capabilities across various domains, ranging from knowledge of farm operations to advanced data analytics and the ability to offer solutions that integrate easily and smoothly with other platforms and adjacent industries. For example, data gathered by autonomous tractors should seamlessly flow to the computer controlling irrigation devices, which in turn should be able to use weather-station data to optimize irrigation plans.

Connectivity pioneers in the industry, however, have already started developing these new capabilities internally. Organizations prefer keeping proprietary data on operations internal for confidentiality and competitive reasons. This level of control also makes the data easier to analyze and helps the organization be more responsive to evolving client needs.

But developing new capabilities is not the end game. Agriculture players able to develop partnerships with telcos or LPWAN players will gain significant leverage in the new connected-agriculture ecosystem. Not only will they be able to procure connectivity hardware more easily and affordably through those partnerships, they will also be better positioned to develop close relationships with farmers as connectivity becomes a strategic issue. Input providers or distributors could thus find themselves in a connectivity race. If input providers manage to develop such partnerships, they could connect directly with farmers and cut out distributors entirely. If distributors win that race, they will consolidate their position in the value chain by remaining an essential intermediary, closer to the needs of farmers.

The public sector also could play a role by improving the economics of developing broadband networks, particularly in rural areas. For example, the German and Korean governments have played a major role in making network development more attractive by heavily subsidizing spectrum or providing tax breaks to telcos.[6] Other regions could replicate this model, accelerating development of connective products by cost-effectively giving input providers and agritech companies assurance of a backbone over which they could deliver services. Eventual deployment of LEO satellite constellations would likely have a similar impact.

► **What Does Sustainable Agriculture Mean for Grain Growers and Ag Retailers?**

Jun 2023 | https://www.dtn.com/what-does-sustainable-agriculture-mean-for-grain-growers-and-ag-retailers/

For farmers and agribusinesses, the idea of sustaining farmland for future use is not new. For decades, they have understood the need to care for the land to protect their livelihood and the environment. But now, people outside the industry are paying attention to how crops are grown, as an increasing number of food companies, grain buyers, and consumers seek ingredients grown using sustainable practices.

The phrase sustainable agriculture has gone from buzzword to mainstream terminology as many food, pet food, and biofuel businesses aim for low emission or zero net carbon targets. It means that sustainability in agriculture is here to stay — whether that's through companies setting environmental, social, and governance (ESG) goals, as a part of climate-smart initiatives, or by consumers demanding greener products.

And with increased attention on agricultural practices are increased market opportunities for agribusinesses and grain growers. But what is sustainable agriculture, and is it any different from what farmers are doing already?

Sustainable ag vs. regenerative ag vs. conservation programs

If we think about types of agricultural practices, conservation programs, regenerative agriculture, and sustainable agriculture probably come to mind. Many of the practices farmers use fit into all these approaches, so the difference between conservation, regenerative ag, and sustainable ag can be a little unclear.

An increasing number of food companies, grain buyers, and consumers are seeking ingredients grown using sustainable practices.

A simple way of looking at regenerative ag vs. sustainable ag is that regenerative agriculture aims to restore the land — for example, improving the organic matter and carbon content of the soil, increasing biodiversity, or improving water retention and quality — and typically has a finite goal. In contrast, sustainable agriculture is a continual practice that aims to restore, if necessary, and then permanently maintain natural resources to ensure the land is viable for future generations.

Conservation programs can, in practice, be regenerative, sustainable, or a blend of the two, as they can be both restorative and protective. For example, the USDA conservation reserve program (CRP), which has been running for more than 35 years, has successfully reduced soil erosion, decreased nitrogen and phosphorus runoff, sequestered greenhouse gases, restored over 3 million acres of wetlands, and benefited wildlife.

Similarly, agricultural practices don't have to be exclusively regenerative or sustainable. Cover crops are a good example of this. Planting cover crops can improve soil health and water quality (regenerative), but they can also reduce erosion and nutrient loss and increase drought resistance (sustainable). Both practices are desirable in some situations.

Sustainable agriculture isn't just about protecting the environment

The main difference between sustainable and regenerative agriculture is the human component. Regenerative ag generally focuses on improving the land — although it can have economic benefits — while sustainable ag considers economic and social factors as well. For example, farmer profitability and fair treatment and wages for farm workers are part of sustainable agriculture. If we consider the USDA's definition, sustainable agriculture not only satisfies human food and fiber needs, improves environmental quality, and uses resources efficiently, but it also sustains the economic viability of farm operations and enhances the quality of life of farmers and society.

Most sustainable agriculture definitions include environment, economy, and society components, although the full definition can vary. If a business has a goal to source sustainably grown ingredients, they likely have their own standards for which ingredients are considered sustainably produced. For example, Nestlé and Unilever have their own definitions and guidelines for sourcing sustainable products. Nestlé is aiming for 100% of their key ingredients to be produced sustainably by 2030, and they source ingredients according to their Responsible Sourcing Standard. Unilever also has a goal of 100% sustainable sourcing of their key agricultural crops, and they have their own sustainable agriculture code and regenerative agriculture principles that they introduced to improve the sustainability of farming operations from which they source ingredients.

The sustainable ag market is ripe for the picking

The increased interest in sustainability in agriculture by food companies, the biofuel industry, and consumers is a growing opportunity for ag businesses and farmers. The emerging market for sustainably

grown grain is a good example. For food businesses looking to "green the food chain," sustainably grown grain meets their desire — and their customers' — for lower carbon emissions, reduced pollution, and healthier grains.

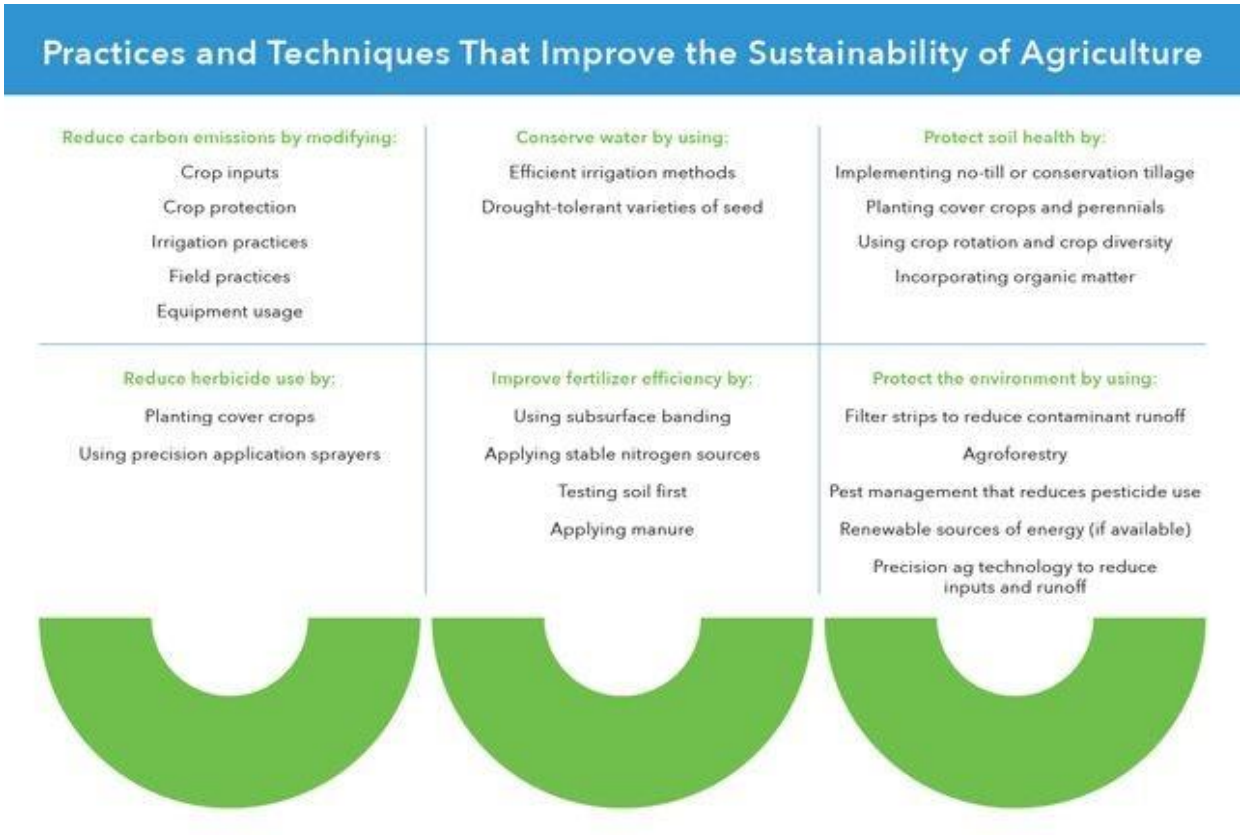
Agribusinesses can find opportunities in the sustainable grain market by helping their customers implement sustainable practices and improving their farms' carbon footprints.

Agribusinesses can find opportunities in the sustainable grain market by helping their customers implement sustainable practices and improving their farms' carbon footprints. For example, they can offer premiums for seed, inputs, and crop protection practices that help reduce carbon emissions and consult on precision farming and carbon credit programs. Ag retailers also have the opportunity to become the knowledge experts on government grants and other resources — like the USDA Partnerships for Climate-Smart Commodities — that incentivize farmers to use sustainable agriculture practices, helping to support their customers and increase their business prospects.

For grain growers, sustainable agriculture practices have positive impacts on not only their land and crops but also the price of the grain they grow sustainably. As more companies set goals that require sourcing sustainably grown ingredients, it's conceivable that premiums, new market opportunities, or carbon credits will be offered for sustainable grain. As previously mentioned, there are also financial incentives available for farmers to switch to sustainable agriculture practices.

Sustainable practices aren't new, but using more of them might be

For grain growers who are looking to enter the sustainable grain market, it's likely they're already doing some sustainable agriculture practices, given the overlap between conservation, regenerative ag, and sustainable ag. But there may be additional opportunities for them to reduce their carbon emissions or use resources more efficiently. Some examples of practices that improve the sustainability of agriculture are listed in the graphic below.



What does the future look like for sustainable grain?

According to global research by SkyQuest, growing consumer demand is predicted to drive the sustainable agriculture market past $28.53 billion by 2030 at a compound annual growth rate (CAGR) of 9.9% from 2022 to 2030. And as the sustainable agriculture market grows, data and technology will need to grow with it.

Greening the food supply chain requires efficient methods to connect grain buyers with sustainable grain growers, and buyers will want to be assured that the grain they're buying *really* was grown sustainably. Accurate and dependable measurement and management tools will be needed to track carbon footprints and manage offsets.

Growing consumer demand is predicted to drive the sustainable agriculture market past $28.53 billion by 2030 at a CAGR of 9.9% from 2022 to 2030.

Agribusinesses can help green the food chain by encouraging more farmers to convert to — or use more — sustainable agriculture practices and ultimately increase the acres of land farmed sustainably. Data technology can be used to help ag businesses identify customers engaging in sustainable practices to allow them to target their sustainable products and services marketing efforts. But that data will need to be accurate and reliable and from credible sources for targeting to work and be useful for ag retailers.

Protecting our planet and our people

Agriculture is moving toward a more sustainable future, one that includes supporting the people at the heart of it. Sustainable agriculture has many definitions, but ultimately, it's ensuring we look after the environment, farmland, and community now — and in the future — to ensure we have the resources we need for generations to come. For grain growers and agribusinesses, sustainable agriculture opens the door

for more market opportunities by building upon the practices they've been investing in for years anyway. It's a win-win for everyone.

► **How ag-tech can improve sustainable agriculture**

Aug 2020 | https://www.alltech.com/blog/how-ag-tech-can-improve-sustainable-agriculture

Consumers are asking more questions about the meals on their tables: Where is my food grown? How is it grown? Is it sustainable? Is it environmentally friendly? This shift in consumer preference is changing the way that corporations work, because now, sustainability must become a permanent line item in their business plans. Not only is sustainably produced food becoming a non-negotiable for consumers and businesses, it also happens to be a solution to feeding the world.

At the Alltech ONE Virtual Experience, Ciarán Black, owner of Nuevo Growth, hosted a discussion with Ryan Rakestraw, director at Temasek International, and Claudia Roessler, director of agriculture for Microsoft, to further discuss how to sustainably produce more food. The consensus? Via **sustainable agriculture** technologies. There are many forms of ag-tech — from technologies that help with the efficiency of how food is produced to technologies that create sustainable packaging and even technologies that can reduce food waste.

"Now, ag-tech is making substantial progress. It's one of the fastest growing areas, but it still remains one of the most under-invested subsectors in the global startup ecosystem," said Black. So, if ag-tech is a solution, what needs to be done to hasten its road to success? Black proposed three methods:

Encouraging investments in ag-tech

Identifying sustainable agriculture technologies

Stressing the urgency around a sustainable food supply

Investments: How can we make sustainable ag-tech more attractive to investors?

As awareness of sustainability grows, investors are taking notice. Rakestraw says there is a strong drive for sustainability today amongst most groups, including:

Consumers. Consumers want to know the environmental impact of their purchases, and this influences a majority of their buying decisions.

Businesses. Businesses are appointing directors with a sustainability agenda because consumers will continue to demand it.

Farmers. In fact, Rakestraw says that most farmers are already environmental stewards.

"They're looking after their land, they're thinking about passing the farm on to the next generation, so this is something that they're certainly thinking about and interested in," he said. "I just don't think they've had a good way to act on this."

Because sustainability is, historically, an interest of farmers, is currently an interest of consumers and is now an interest of businesses, investors are primarily focused on companies that have implemented sustainability methods.

"The question is, **if you don't have some type of sustainability agenda or the ability to influence sustainability in your product or service, will you even continue to exist?**" asked Rakestraw.

So, how can we ensure that we will continue to drive this sustainability agenda — especially when farmers, according to Roessler, are notoriously "late bloomers" when it comes to digital trends and advancements? There are many sustainable deliverables farmers need to achieve, including:

Growing more while using fewer resources

Tracking and measuring their sustainable footprint

Telling consumers how their food was produced and where it's coming from

Farmers need digital and data-related innovations on their farms in order to meet these deliverables, and luckily, as Roessler noted, "the amounts that are being invested in the ag-tech industry are increasing over the last couple of years."

Investments are imperative for startups, universities and research organizations that have the goal of developing sustainable, environmental and agricultural practices.

"This is from anything like detecting pest stress or disease stress on a farm in a certain region to smart irrigation in another region," said Roessler. "So, we want to help harness this ecosystem."

It's about more than just investing, though, and Roessler uses Microsoft's startup programs as an example: They not only help invest but also help adjust the footprint, monitor sustainability goals, develop the process, market the products and deliver them to the buyer. Investors need to nurture startups to stimulate success. With this nurturing comes the speed that is necessary to "drive innovation at the speed that's needed to address all those environmental changes."

Identification: Where are the applications that can help agriculture create a Planet of Plenty?

Now that sustainability is on investors' radars, it comes down to identifying sustainable ag-tech startups. Which startups should we be looking into? According to Roessler, we need to be looking at technology that increases productivity by growing more food that uses:

- Less energy
- Less land
- Less water

This is especially important because productivity has one of the biggest impacts on the environment.

"Think about if you could use 1.5 billion (fewer) acres of land in agriculture," said Roessler. "This would be a significant purpose to what's in our environmental goals."

Another area to identify is risk prevention. Ag-tech that can monitor farms and the environment prevents incidents that lead to:

- Food safety issues
- Food waste
- Disease
- Abnormalities

Overall, Roessler stresses that it's critical to address these issues before they arise, which will ultimately **improve our whole food production process.**

"I think that's really the ultimate goal, which we need to enable now," stressed Roessler.

Black then expanded on these points by reiterating the importance of identifying ag-tech that mitigates risk and creates a link to help the consumer understand sustainability within the supply chain.

But it doesn't just stop at risk detection; Rakestraw listed several additional technologies that warrant investments, including:

Gene editing and precision breeding systems for crops and livestock

Insights around the microbiome and the use of synthetic biology tools

Sustainable packaging of food products, using less packaging or biodegradable materials while still maintaining the safety and shelf life of the product

Rakestraw specifically highlighted the importance of ag-tech that **reduces food waste**, "whether that's new coating technologies, optimized logistics or predictive analytics associated with matching supply and demand."

Urgency: Will we embrace ag-tech quickly enough?

The growing population and increased environmental education add a sense of urgency to identifying sustainable ag-tech to invest in.

"So, we know that agriculture is becoming more sustainable, but just not fast enough," said Black. "Is there anything we can do to increase the pace of that change? How do we go about doing that?"

Rakestraw listed three possible solutions:

Industry collaboration — and not just within animal health and nutrition, but across industry segments. Through this collaboration, we will be able to educate consumers through quantifying and showcasing benefits.

Public and private partnerships with government and industry to define standards, quantify metrics and regulate the messaging to convey to the consumer.

Be bold and take some risks with moonshot goals associated with sustainability.

"I think the onus is on not only us as investors but (as an) industry to find these technologies that could have a significant impact and support them and help them come to life in this 10-year, 20-year, 30-year time period," explained Rakestraw.

Digital technologies can increase the collaboration between startups, corporations and government. Will fast-paced industry collaborations lead us into a more sustainable future?

Roessler says yes, but not by itself. **We need to build programs that are sustainable for many years — not just short-term initiatives.** The societal impact of agriculture requires creating infrastructures like internet connectivity for rural farms and fostering talent in agriculture that can work with technology in the future.

While speed is important, Roessler says that longevity is also key. We need innovations quickly, but we also need to look at how technology evolves and stays current.

"This is really (something) we're in for the long run, and I think that's really what's needed to drive a systemic change in the industry," said Roessler.

Final thoughts

By attracting investors, identifying technologies and urging quick action, we can anticipate a strong push in sustainable ag-tech for our futures. With the population growing rapidly, the industry has a collective duty to ensure food for the masses, and nurturing farms through new technologies can make this happen. Because, as Black stated at the beginning of his discussion, "Agriculture has the potential to provide solutions, both to feeding the planet and combating climate change — but we must do both."

Cellulose & Fiber Extraction

► **Global Cellulose Market - Industry Trends and Forecast to 2030**

Jul 2023 | https://www.databridgemarketresearch.com/reports/global-cellulose-market

Cellulose Market Analysis and Size

Data Bridge Market Research analyses that the global cellulose market, which was USD 40.56 billion in 2022, would rocket up to USD 93.10 billion by 2030 and is expected to undergo a CAGR of 9.67% during the forecast period of 2023 to 2030.

Cellulose is used as cellulose derivatives such as acetate, cellulose ethers, and cellulose esters. These derivatives have applications in various industries, including pharmaceuticals, food, textiles, and cosmetics. They are used as thickeners, stabilizers, emulsifiers, and film-forming agents, among other functions.

The natural source segment is expected to dominate the global cellulose market due to its sustainable and renewable nature, making it a preferred choice for environmentally conscious industries and consumers.

“Natural” dominates the source segment of the cellulose market due to its sustainable and renewable nature, making it a preferred choice for environmentally conscious industries and consumers.

In addition to the insights on market scenarios such as market value, growth rate, segmentation, geographical coverage, and major players, the market reports curated by the Data Bridge Market Research also include in-depth expert analysis, geographically represented company-wise production and capacity, network layouts of distributors and partners, detailed and updated price trend analysis and deficit analysis of supply chain and demand.

Cellulose Market Scope and Segmentation

REPORT METRIC	DETAILS
Forecast Period	2023 to 2030
Base Year	2022
Historic Years	2021 (Customizable to 2015-2020)
Quantitative Units	Revenue in USD Million, Volume in Tons, Pricing in USD
Segments Covered	By Source (Natural, Fruits, and Treewood), Modification (Unmodified andModified), Manufacturing Process (Viscose, Cellulose, and Ethers), Purity (Above 95%, 85% - 95%, and Below 85%)
Countries Covered	North America (U.S., Canada, and Mexico), South America (Brazil, Argentina, and Rest of South America), Europe (Germany, France, Italy, U.K., Belgium, Spain, Russia, Turkey, Netherlands, Switzerland, and Rest of Europe), Asia-Pacific (Japan, China, India, South Korea, Australia, Singapore, Malaysia, Thailand, Indonesia, Philippines, and Rest of Asia-Pacific), Middle East and Africa (U.A.E., Saudi Arabia, Egypt, South Africa, Israel, and Rest of the Middle East and Africa)
Market Players Covered	Ashland (U.S.), Shin-Etsu Chemical Co., Ltd. (Japan), Dow (U.S.), CP Kelco (U.S.), Akzo Nobel N.V. (Netherlands), LOTTE Chemical CORPORATION

	(South Korea), China RuiTai International Holdings Co., Ltd. (China), DKS Co. Ltd. (South Korea), Daicel Finechem Ltd. (Japan), Fenchem (China), J. RettenmaierandSöhne GmbH + Co.Kg (Germany), Lotte Fine Chemical (South Korea), Reliance Cellulose Products Ltd. (India), SE Tylose GmbH and Co. Kg (Germany), Shandong Head Co., Ltd. (China), Shin-Etsu Chemical Co. Ltd. (Japan), MAZRUI INTERNATIONAL (U.A.E.), Zhejiang Kehong Chemical Co. Ltd. (China), Rayonier Inc. (United States), Tembec Inc. (Canada), Borregaard (Norway)
Market Opportunities	Growing demand for sustainable and biodegradable materials Rapid expansion of the textile and apparel industry

Market Definition

Cellulose refers to various cellulose-based products and derivatives used across industries, including paper and pulp, textiles, pharmaceuticals, food and beverages, cosmetics, and construction. These products and derivatives are typically derived from natural sources such as wood pulp, cotton, or agricultural residues and are valued for their structural properties, biodegradability, and sustainability.

Global Cellulose Market Dynamics

Drivers

Growing demand for sustainable and eco-friendly materials

Cellulose, generally derived from renewable sources such as wood pulp and cotton, is considered a sustainable alternative to synthetic materials. The increasing focus on sustainability and environmental concerns drives the demand for cellulose in various industries. Moreover, technological advancements are driving market growth by enabling the development of innovative cellulose-based products.

Rising demand from the textile industry

Cellulose fibers are extensively used in the textile industry for producing fabrics and garments. The growing fashion industry and changing consumer preferences towards comfortable and natural fabrics drive the demand for cellulose fibers. Moreover, rapid expansion of the textile and apparel industry drives global cellulose market growth.

Restraint

Availability of alternative materials

Cellulose is known for its sustainability benefits however, cellulose faces competition from synthetic materials and other natural fibers. The availability of alternative materials with similar properties and lower costs restrain the growth of the cellulose market in some applications.

Opportunity

Increasing demand for cellulose nanofibers

Cellulose nanofibers, known for their exceptional strength, lightweight nature, and high aspect ratio, have a wide range of potential applications in various industries, including composites, automotive, aerospace, and construction. The increasing demand for lightweight and high-performance materials opens doors for cellulose nanofibers in these sectors.

Challenge

Volatility of raw material prices

The production of cellulose requires raw materials that may have fluctuations in availability and prices and can significantly impact the production costs of cellulose. Supply chain disruptions, geopolitical factors, and changing market dynamics can contribute to raw material price volatility.

This global cellulose market report provides details of new recent developments, trade regulations, import-export analysis, production analysis, value chain optimization, market share, the impact of domestic and localized market players, analyses opportunities in terms of emerging revenue pockets, changes in market regulations, strategic market growth analysis, market size, category market growths, application niches and dominance, product approvals, product launches, geographic expansions, technological innovations in the market. To gain more info on the global cellulose market contact Data Bridge Market Research for an Analyst Brief, our team will help you make an informed market decision to achieve market growth.

Recent Development

In February 2023, Japanese multinational company Asahi Kasei completed the construction of its second plant for Ceolus™ microcrystalline cellulose (MCC) at its Mizushima Works in Japan. The new facility aims to meet the growing demand for MCC, particularly in pharmaceutical tablets.

► **Cellulose Fiber Market**

Jul 2022 | https://www.futuremarketinsights.com/reports/cellulose-fiber-market

The global Cellulose Fiber Market is expected to be valued at US$ 3,825.6 Million in 2022, expected to reach US$ 5,772.7 Million by 2032. A CAGR worth 4.2% is expected for the market during the 2022-2032 forecast period. Companies are looking for alternatives to petrochemical-sourced fibers and are shifting towards environment-friendly and biodegradable fibers, which is increasing demand for cellulose fibers around the world and is expected to propel the growth of the cellulose fiber market during the forecast period.

Furthermore, because cellulose fibers are widely utilized in the textile and garment industries, global growth in the textile and apparel industries is increasing demand for cellulose fiber and is expected to drive the cellulose fiber market in the future years.

Cellulose fiber is the result of several operations performed on wood pulp derived from plant bark, leaves, and wood. To generate cellulose fiber, this wood pulp goes through several chemical steps. Cotton fiber, rayon, flax fiber, and viscose are all examples of cellulose fiber. Some of the most common uses for cellulose fiber are in textiles, fabrics, and filters.

Report Attribute	Key Statistics
Expected Market Value (2022)	US$ 3,825.6 Million
Projected Forecast Value (2032)	US$ 5,772.7 Million
Anticipated Growth Rate (2022-2032)	4.2%

The industrial processing of wood pulp generated from botanical sources is included in the manufacturing of synthetic or man-made fibers. However, the production of cellulose fibers necessitates the mechanical and chemical processing of wood pulp. The most prevalent rayon variations are triacetate, viscose, and acetate,

which are man-made cellulose fibers utilized extensively across end-use industries. Such materials are going to accelerate the demand of cellulose fiber market during the forecast period.

What Are The Major Factors Boosting The Cellulose Fiber Market?

The rising attention of the world on finding an environmentally friendly and biodegradable fiber is one of the primary factors complementing the cellulose fiber market expansion. As the topic of climate change, environmental pollution, and sustainability has gained traction, an increasing number of businesses are attempting to transition away from the traditionally utilized petrochemical-sourced fibers, which emit enormous amounts of carbon into the environment.

As a result, cellulose fibers are gaining demand, which is expected to increase further throughout the forecast period, offering a boost to the cellulose fiber market's growth. For example, when looking for a replacement for glass-fiber-reinforced polymers, the German Institutes for Textile and Fiber Research Denkendorf (DITF) created PURCELL. Since the material is composed entirely of cellulose, it is completely recyclable. With increased urbanization and consumer purchasing power, there is a shift from need-based to aspiration-based purchases, which is driving up demand for textiles and apparel.

As cellulose fibers are widely utilized in the textile industry, the rise in per capita income and increase in consumer spending throughout the world are driving the growth of the textile and clothing sector, which is expected to drive the growth of the cellulose fiber market during the forecast period.

What Are the Factors Hindering the Cellulose Fiber Market?

The cost of cellulose fiber has been a major impediment to the expansion of the global cellulose fiber industry. The prices of raw materials used in the production of cellulose fiber are volatile and change on a regular basis, limiting their use in large-scale companies.

The industry is highly capital intensive, with significant investment in knowledge and cash. The industry's biggest barrier is the large investment in research and development efforts for generating new technologies or products. Furthermore, frequent changes in raw material prices, diminishing cotton supply, and rigorous environmental regulations regarding forests imposed by governments around the world pose significant challenges to the sector.

In addition, competent workers and specialized machinery are necessary in the production of cellulose fiber, which is extremely difficult to come by. The aforementioned issues have surfaced as impediments to the expansion of the global cellulose fiber market.

What Is The Outlook the North American Cellulose Fiber Market?

In terms of market share and revenue, North America is expected to grow steadily throughout the projection period of 2022-2032. The analysts at Future Market Insights predict that by 2022, the market of Cellulose Fiber in North America is expected to acquire a global market size of 23%.

North America is always active in the research and development process for cellulose fiber advancement. As a result, North America is predicted to grow at a robust rate over the forecast period.

This expansion is due to increased demand in the textile and industrial sectors. The region is expected to exhibit a similar growth trend during the estimated period due to increased demand from the region's textile, industrial, and other application segments.

How Is the European Market Driving Demand For Cellulose Fiber?

By 2022, Europe will hold approximately 20% of the global market share. This region is expected to grow steadily during the forecast period, 2022-2032. Europe is predicted to show moderate development in the global cellulose market, since raw resources for the production of cellulose fiber are abundant.

A burgeoning population and improved living standards are driving demand for textiles in this sector. Natural and synthetic cellulose fibers are extensively used to make textiles. Apparel and home textile are the primary applications predicted to fuel market growth in the European region in the coming years.

Natural cellulose fibers and man-made cellulose fibers are the two most frequent forms of cellulose fibers. Cotton, jute, and other natural cellulose fibers are examples of organic cellulose fibers, whereas man-made cellulose fibers include viscose, lyocell, modal, and others. The increased demand for various cellulose fibers is assisting the regional market expansion.

Market Competition

The cellulose fibers market is capital demanding and requires specialized knowledge. Market participants are continually involved in research and development for new products and technological developments to enhance the knowledge.

The key players of this market include Sappi group, Birla Cellulose, Tembec Inc., The Lenzing Group, Thai Rayon Public Co. Ltd., Tangshan Sanyou Group Xingda Chemical fiber Co. Ltd., Fulida Group Holding Co., LTD., Ioncell, Bacterial Cellulose Solutions, Manasi Aoyang Technology Co. Ltd.

In 2022, Sappi committed to being a part of the solution and is working to decarbonize its operations. It will cease the use of coal at its German location in Stockstadt as a next step in its long-term global commitment to climate preservation and sustainable production. To that purpose, the mill's current coal-fired Boiler 9 will be dismantled, and the mill will run solely on renewable biomass and natural gas.

Start-up scenario

Bacterial Cellulose Solutions is a firm established in the United States that launched a bacterial cellulose-based wound healing product in 2021. The startup's bacterial cellulose substance functions as a biological barrier to bacterial invasion and keeps the skin surface wet and warm. This procedure relieves pain and keeps the incision from becoming infected. Bacterial Cellulose's solution can be customized in terms of thickness, opacity, texture, and mechanical qualities to fit the needs of the customer.

In 2021, Ioncell, a Finnish firm, will launch a patented technology to improve the strength and endurance of cellulose-based fibers. Through a sequence of dissolving and dry-jet wet spinning processes, recycled fibers from textile items are transformed into strong fibers using non-toxic ionic liquid and water. It recycles used textiles, pulp, and old newspapers with low environmental impact. The end result is a moisture-absorbing, biodegradable, glossy, and dyeable fabric similar to cotton and viscose.

- **Cellulose Fiber Market Size, Share Global Analysis Report, 2022 – 2028**

Sep 2020 | https://www.fnfresearch.com/cellulose-fiber-market

According to Facts and Factors,The global cellulose fiber market size was worth USD 35.20 billion in 2021 and is estimated to grow to USD 60.01 billion by 2028, with a compound annual growth rate (CAGR) of approximately 9.30% over the forecast period. The report analyzes the cellulose fiber market's drivers, restraints/challenges, and their effect on the demands during the projection period. In addition, the report explores emerging opportunities in the cellulose fiber market.

Market Overview

Cellulose fiber refers to synthetic fibers from plant stalks or the cellulose found in wood pulp. These fibers are naturally adaptable and have special qualities like moisture absorption and hydrophobicity, among others. Natural and artificial cellulose fibers are the two basic categories into which cellulose fibers are divided. Cotton, jute, and other natural fibers are examples of cellulose, whereas man-made cellulose fibers include viscose, lyocell, modal, and other materials. Synthetically produced man-made cellulose fibers are less expensive and more environmentally friendly than their synthetic counterparts. However, they need

much more water and energy in processing than other things. Each type of fiber has certain beneficial properties that are acquired through a variety of chemical processes. The rise in per capita income and increase in consumer spending worldwide are driving the growth of the textile and clothing sector, which is anticipated to drive the growth of the cellulose fiber market during the forecast period. It is because cellulose fibers are widely used in the textile industry.

COVID-19 Impact:

The ailment has spread to almost every nation on Earth since the COVID-19 infection flared up in December 2019, and the World Health Organization has declared it a global health catastrophe. The global repercussions of the Covid disease 2019 (COVID-19) are just starting to be realized, and they will largely affect the cellulose fiber industry in 2020. The COVID-19 flare-up has had positive effects, including flight cancellations, travel boycotts, isolation, café closures, and restrictions on all indoor and outdoor events. It has also caused a significant slowdown in production, increased market volatility, declining business confidence, rising populist hysteria, and future vulnerability in more than forty countries.

Key Insights

As per the analysis shared by our research analyst, the global cellulose fiber market value is expected to grow at a CAGR of 9.30% over the forecast period.

In terms of revenue, the global cellulose fiber market size was worth USD 35.20 billion in 2021 and is estimated to grow to USD 60.01 billion by 2028.

The global focus on developing eco-friendly and biodegradable fiber is one of the main factors promoting the growth of the cellulose fiber market.

By process of manufacturing, the natural cellulose fiber category dominated the market in 2021.

By application, cellulose fiber for the textile segment dominated the market in 2021.

The Asia Pacific dominated the cellulose fiber market in 2021.

Growth Drivers

Increased focus on environmentally friendly and biodegradable fiber drives the market growth

One of the key elements supporting the growth of the global cellulose fiber market is the increasing focus on finding environmentally friendly and biodegradable fiber around the globe. An increasing number of companies are striving to shift away from conventionally used petrochemical-sourced fibers, which emit vast amounts of carbon into the environment, as the topic of climate change, environmental pollution, and sustainability has gained popularity.

As a result, the demand for cellulose fibers is rising. It is anticipated to do so further throughout the forecast period, supporting the expansion of the cellulose fiber market. For instance, the German Institutes for Textile and Fiber Research Denkendorf (DITF) developed PURCELL as an alternative for glass-fiber-reinforced polymers. The product is 100% recyclable because it is made entirely of cellulose. Demand for textiles and clothing is rising due to a change from need-based to aspiration-based purchases brought on by greater urbanization and consumer spending power.

Restraints

The high cost of cellulose fiber may hinder the market growth

The cost of cellulose fiber has severely constrained the global cellulose fiber industry's growth. Large-scale businesses are constrained in their utilization of raw materials because of how unstable and frequently changing their prices are.

The industry requires a considerable investment in knowledge and capital and is very capital-intensive. The industry's biggest obstacle is the significant investment in research and development needed to produce new technology or goods. Additional difficulties for the industry include:

Regular variations in raw material prices.

A decreasing supply of cotton.

Governments impose strict environmental restrictions involving trees all over the world.

Manufacturing cellulose fiber, which is very hard to come by, requires skilled labor and specialized equipment. The problems above have emerged as roadblocks to the growth of the global market for cellulose fiber.

Segmentation Analysis

The cellulose fiber market has been segmented into the manufacturing, application, and region.

The global cellulose fiber market is divided into natural cellulose fiber, manufactured cellulose fiber, semi-synthetic and synthetic based on manufacturing. The natural cellulose fiber category dominated the market in 2021. Plants are harvested and processed to provide natural cellulose fibers as needed. They are separated from the remainder of the plant during processing, which is useless.

The global cellulose fiber market has been divided into cellulose fiber for textiles, cellulose fiber for filtration, and cellulose fiber for composite materials based on application. The cellulose fiber for textiles segment dominated the market in 2021. In the textile industry, fibers are mostly used to filter pollutants and strengthen composites. Consequently, fiber made from wood pulp is increasingly significant for the textile sector. The primary raw material used in the textile industry is cotton. However, the difficulties in growing cotton have led to a decline in production, significantly increasing the demand for cellulose fibers made from wood. These exhibit high performance and are used in industrial, domestic textile, garment, etc.

Recent Developments

In 2021: A Finnish company called Ioncell will introduce a patented method to enhance the durability and strength of fibers made of cellulose. Recycled textile fibers are converted into strong fibers utilizing water and a non-toxic ionic liquid through a series of dissolving and dry-jet wet spinning processes. Low environmental effect recycling of pulp, used textiles, and outdated newspapers. The ultimate product is a glossy, biodegradable, moisture-absorbing fabric that may be dyed, much like cotton and viscose.

Report Scope

Report Attribute	Details
Market Size in 2021	USD 35.20 billion
Projected Market Size in 2028	USD 60.01 billion
CAGR Growth Rate	9.30% CAGR

Base Year	2021
Forecast Years	2022-2028
Key Market Players	Sappi Group, Tembec Inc., Birla Cellulose, Thai Rayon Public Co. Ltd., The Lenzing Group, Xingda Chemical Fiber Co. Ltd., Tangshan Sanyou Group, Ioncell, Fulida Group Holding Co. LTD., Bacterial Cellulose Solutions, Manasi Aoyang Technology Co. Ltd., and Others
Key Segment	By Manufacturing, Application, and Region
Major Regions Covered	North America, Europe, Asia Pacific, Latin America, and the Middle East &, Africa
Purchase Options	Request customized purchase options to meet your research needs. Explore purchase options

Regional Landscape

The Asia Pacific dominated the cellulose fiber market in 2021

The Asia Pacific dominated the global cellulose fiber market in 2021 due to strong demand in the industrial and textile sectors. Due to the increase in demand from industrial, textile, and other application segments in the region, it is predicted to exhibit a similar growth trend over the expected period. The region's main markets include China, India, Japan, South Korea, Pakistan, Taiwan, and Indonesia. Fibers, utilized in various end-use sectors, are manufactured and traded in these nations. The product's prospective future markets are Bangladesh and Vietnam. However, over the next nine years, it is anticipated that strict forestry laws will impede the product's growth.

Competitive Landscape

- Sappi Group
- Tembec Inc.
- Birla Cellulose
- Thai Rayon Public Co. Ltd.
- The Lenzing Group
- Xingda Chemical Fiber Co. Ltd.
- Tangshan Sanyou Group
- Ioncell
- Fulida Group Holding Co. LTD.
- Bacterial Cellulose Solutions
- Manasi Aoyang Technology Co. Ltd.

► **Regenerated Cellulose Market**

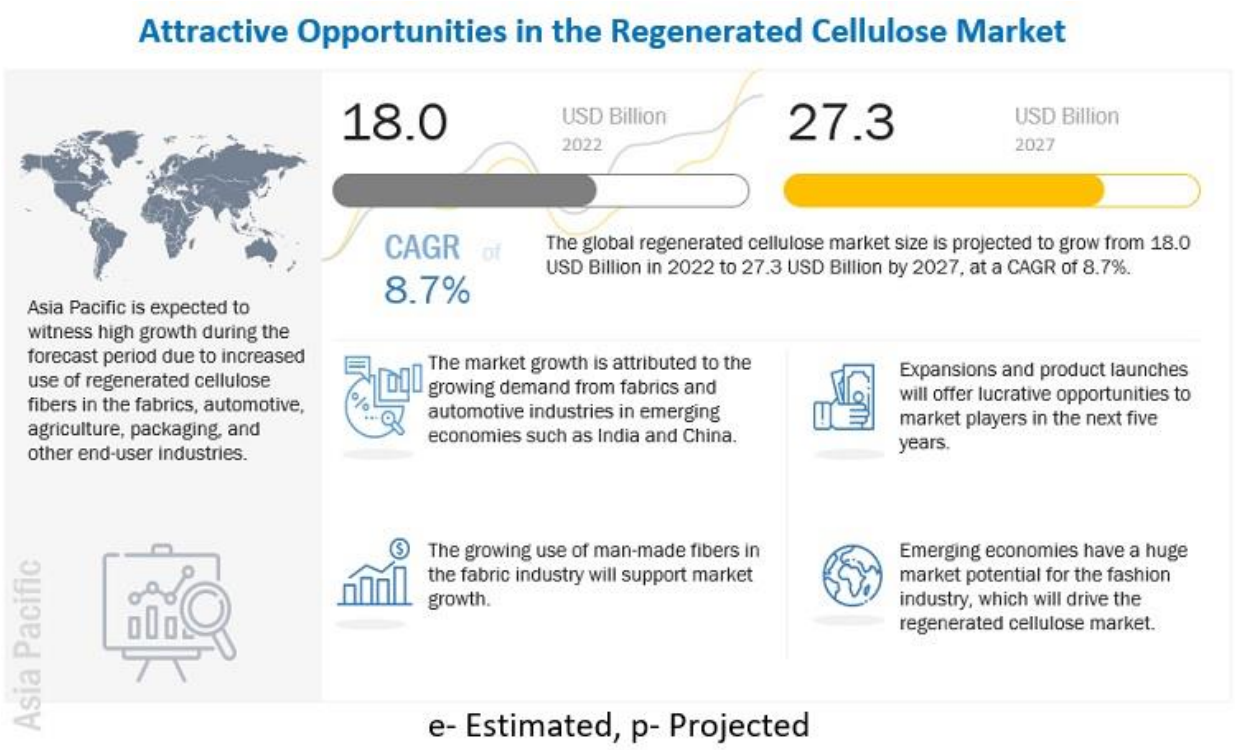
Sep 2022 | https://www.marketsandmarkets.com/Market-Reports/regenerated-cellulose-market-99265926.html

Regenerated Cellulose Market

The global regenerated cellulose market was valued at USD 18.0 billion in 2022 and is projected to reach USD 27.3 billion by 2027, growing at a cagr 8.7% from 2022 to 2027. Regenerated cellulose is a group of materials that are produced simply from the natural cellulose via physical dissolution and regeneration. The regeneration is the eco-friendly process in which the re-usage of harmful chemicals can occur. Nowadays, the rising demand for eco-friendly fibers from various end-use industries such as Fabric Industry, Automotive Industry, Agriculture Industry, Packaging Industry, and others is driving the market for regenerated cellulose. The key factors which fuelled the growing demand for regenerated cellulose in emerging economies are the adoption of new innovative manufacturing technologies, changing lifestyles, rapid urbanization, and others.

The increasing awareness about personal hygiene, biodegradability, and sustainability is the key factor in increasing the demand from various end-use industries such as the fabric industry, automotive industry, agriculture industry, packaging industry, and others are generating new opportunities for the market. The products from regenerated cellulose are environment-friendly and biodegradable in nature, which helps to penetrate the wide market of regenerated cellulose.

Regenerated Cellulose Market



COVID-19 Pandemic Impact

Due to the COVID-19 pandemic, there was a disruption in the supply chains, a decline in the demand of end-use industries, and a shortage of labour which led to the suspension of operation resulted in the declined

growth of the regenerated cellulose market. However, during the COVID-19 pandemic period, the demand for medical and nutrition goods was rising supporting the market for regenerated cellulose. Additionally, the rapid recovery of several end-use industries such as automotive, agriculture, and fabric will support the growth of the market in the forecast period.

Regenerated Cellulose Market Dynamics

Driver: The rising demand for eco-friendly fabrics across the globe drives the market.

The eco-friendly fabrics which are produced from regenerated cellulose drive the market in emerging economies such as India, China, and other ASEAN countries. These fibers help to stabilize the earth's climate by reducing the level of Green House Gas Emissions (GHGs) and other harmful pollutants during the production process. Viscose is the most essential fiber which comes in the category of regenerated cellulose. It constitutes approximately 79% of the share of all artificial cellulose fibers which are used in the textile industry. Due to its excellent breathability, smooth, silky, lustrous, good absorbency, and other good mechanical properties, it is highly used in textile and apparel industries. The demand from these industries is likely to propel the market for regenerated cellulose.

Restraint: Shortage of raw materials and capital-intensive operation

Regenerated cellulose is derived from natural cellulose pulp, and natural cellulose pulp comes from trees that are grown in responsibly managed forests. However, there are many third-party organizations available that have a business in selling natural cellulose pulp, which complies with Sustainable Forestry Initiative (SFI) certification standards. But, there is a scarcity of resources and raw materials such as water and natural cellulose pulp significantly impact the business operations of cellulose fiber manufacturing firms.

Several key manufacturers have created new reservoirs closer to plant locations to have a sufficient supply of water to produce regenerated cellulose fibers. These type of setups requires a huge amount of investment which may not be useful in the long run in the case of societal challenges. For instance, the shortage of wood due to forest degradation and the scarcity of freshwater resources in the world is mainly due to the overuse and wastage of water, which will hamper the operation of the cellulose fiber manufacturing business.

The operational and infrastructural costs of the manufacturing plant mainly depend upon the price of raw materials and application areas for which manufacturers plan to produce regenerated cellulose. As production of pulp and fibers involves energy-intensive processes and hence requires a high amount of investment. This increment in the prices of regenerated cellulose attracts a lower demand from the consumer end. Hence, both shortage of raw material and high prices of the regenerated cellulose affects the market of regenerated cellulose.

Opportunities: Use of Regenerated cellulose in personal care and hygienic products

Regenerated cellulose is produced from the natural cellulose pulp which comes from a wide variety of trees. Hence it is used in making various personal hygiene products such as sanitary pads and diapers owing to their absorbency, flexibility, and reliability properties. Moreover, these products are biodegradable in nature which does not degrade the environment severely. Increasing awareness regarding personal hygiene and the high demand for personal hygienic products are the major key factors that drive the market for regenerated cellulose.

Challenges: Usage of Cellulose acetate products

The market growth of regenerated cellulose can be affected by the Government regulations that ban smoking in public areas. Stringent rules and regulations of the government, due to several health risks associated with smoking are the key factor to restrict the demand for cellulose acetate to a certain extent in the global market. Therefore, cellulose acetate suppliers need to invest significantly to revamp their operations to comply with the new regulations.

Regenerated Cellulose Market Ecosystem



By End Use Industry, Fabric Industry accounted for the highest CAGR during the forecast period

Fabric Industry is the fastest growing end use industry segment for regenerated cellulose market owing to the increasing use of regenerated cellulose in variety of fabrics such as fashionable dresses, ethnic wear, inner wear, outerwear, sportswear, beddings, rugs, draperies, carpets, curtains, blankets, cushions, and many more to provide several charactertics such as comfort, softness, lustre, breathability, absorbency, and others.

By Type, Fibers segment accounted for the highest CAGR during the forecast period

Fibers are estimated to be the quickest rising market during the forecast period owing to increasing demand for eco-friendly products which helps to strengthen sustainability. The regenerated cellulosic fibers have some excellent properties such as high wet tenacity, good absorbency, soft, lustrous, easily dyeable, biodegradability, good drape ability, and others which helps them to use as an alternative to synthetic fibers.

By Source, Wood Pulp accounted for the largest share in 2021

Wood Pulp is estimated to be the largest market for Regenerated Cellulose Market. Regenerated cellulose derived from wood pulp is widely used in several applications, especially where high tensile strength, high wet tenacity, high abrasion resistance, and excellent absorbing capacity are required. With the help of these properties, they are used in wide applications such as in the making of tire cords, farming ropes, and others

By Manufacturing Process, the Regenerated Cellulose Market Viscose segment accounted for the largest share in 2021

Viscose is estimated to be the largest market for Regenerated Cellulose Market. Viscose Manufacturing technology, is used in several end-use industry, especially fabric industry to manufacture fashionable dresses, innerwear, outerwear, sportswear, bedding, curtains, rugs, towels, and others. The viscose technology used to enhance several characteristics of fabrics such as absorbency, lightweight, better

washability , temperature resistance, smoothness, softness, high wet tenacity, high tensile strength, high abrasion resistance, etc.

APAC is projected to account for the highest CAGR in the regenerated cellulose market during the forecast period

APAC is estimated to be the fastest growing market for regenerated cellulose during the forecast period. Regenerated cellulose market is witnessing significant growth in several emerging economies in the region such as India, China, and Japan, owing to the rising awareness regarding rising disposable income, sustaninability and the increasing use of environment friendly raw materials in sevral end-use industries such as fabric, automotive, and packaging industries. Additionally, the growth of end use industries major in the region will further boosts the demand of the regenerated cellulose market.

Regenerated Cellulose Market Players

Regenerated Cellulose comprises major manufacturers such as Sateri (China), Lenzing AG (Austria), Grasim Industries Limited (India), Kelheim Fibres GmbH (Germany), Fulida Group (China), and Eastman Chemical Company (US) are the key players operating in the Regenerated Cellulose Market. Expansions, acquisitions, joint ventures, and new product developments are some of the major strategies adopted by these key players to enhance their positions in the Regenerated Cellulose Market.

Regenerated Cellulose Market Report Scope

Report Metric	Details
Market Size Value in 2022	USD 18.0 billion
Revenue Forecast in 2027	USD 27.3 billion
CAGR	8.7%
Years Considered	2015–2027
Base year	2021
Forecast period	2022–2027
Unit considered	Value (USD Billion), and Volume (Kilotons)
Segments	Type, Source, Manufacturing Process, End User Industry, and Region
Regions	Asia-Pacific, North America, Europe, and the Rest of the World (ROW)
Companies	The major players are Sateri (China), Lenzing AG (Austria), Grasim Industries Ltd. (India), Eastman Chemical Company (US), GP Cellulose, LLC (US), and others are covered in the Regenerated Cellulose market.

Energy Materials & Electrification

► Ag Prepares for Electric-Powered Future

May 2022 | https://www.farm-equipment.com/articles/20408-ag-prepares-for-electric-powered-future

Spurred by global environmental concerns and farmer demands for more economic productivity, some equipment makers are increasingly turning their research and development sights to the efficiencies of the electric motor.

Over the past 5 years, agricultural media reports have traced a sharp rise in OEM interest in electric vehicle (EV) technology to address tightening environmental standards and related consumer demand for "sustainable" on-farm production practices. In 2021, analysts from British market research firm IDTechEx went on the record to predict the market for EVs in agriculture, construction and mining could grow to $100 billion annually.

Developers of electrified equipment for the farm — primarily tractors and skid-steer loaders as of 2022 — also say moving to battery-powered, zero-emission EV technology offers owners significant reductions in fuel and maintenance costs over the life of the machine when compared with diesel-powered equipment of the same capacity. Additionally, developers say all-electric, digitized and automated tractors can significantly lower growers' cost of production by reducing labor requirements and providing on-the-go crop condition data.

Following are 3 drivers of the trend toward electric power.

1. Regulatory Pressure

Regulators in Europe and California continue their quest for zero emissions, despite major improvements in air quality scored by the U.S. Environmental Protection Agency's amendments to the Clean Air Act in 1990. That legislation sparked the overhaul of both North America and Europe's diesel fuel sulfur content and, by 2015, resulted in the completion of 4 tiers of diesel exhaust emission control regulations.

In 2016, the European Union's parliament voted to implement a 5th stage of tougher clean air standards that applied to the smallest and largest off-road engines.

Likewise in late 2021, California's Air Resources Board (CARB) approved its own two-phase Tier 5 stiffened emission standards to cover small off-road engines (SORE) — from leaf blowers to generators — beginning in 2024. In a December news release, CARB announced the first phase of the CARB plan that seeks a 40-90% reduction in emissions based on engine size, and seeks zero emissions from all covered power equipment by 2028 in its second phase.

Gridtractor, a partially owned subsidiary of Polaris Energy Services, launched in California in November 2021, offers fleet electrification services to farmers. California provided Gridtractor an opportunity to utilize extensive electrical infrastructure on farms, incentives for electrification and pilots for vehicle grid integration, the company notes in a statement.

While the EPA maintains jurisdiction in California over emission standards for off-road diesel-powered farm and construction equipment under 175-horsepower, OEMs and independent equipment makers are aware political winds could easily shift, and more stringent rules could be in place overnight.

Changing regulation could drive manufacturers — and farmers — to adopt new practices. Regenerative farming is also becoming popular as consumers demand more sustainable products.

"The drive to more sustainable farming will be incentivized, not only by taxes, grants, credits and things like that," says Rob Dongoski, partner at consultancy group EY and leader of its agribusiness practice, "but I think

we could see some co-investment from food and beverage manufacturers who want sustainable ingredients in their end product."

Some significant buyers of ag commodities have already made commitments to more sustainable crop production practices. General Mills alone, for example, announced that it would work with farmers, suppliers and farm advisors to advance regenerative agriculture on 1 million acres of farmland by 2030. If the path to sustainable products includes EV technology, it may result in a world where the food and beverage industry specifies the need for electric tractors out in the field.

2. Electric Efficiency

The U.S. Dept. of Energy (DOE) and the European Community of Manufacturers of Electric Machines and Power Electronics cite premium electric motors as capable of over 90% efficiency in converting input power to output power. Meanwhile, current computer-controlled, emissions-compliant diesel engines range from 35-45% efficiency in converting chemical energy in fuel to power output.

Kraig Schulz, co-founder and CEO of Autonomous Tractor Corp. (and 2018 keynote presenter at the Precision Farming Dealer Summit), says an electric drive system can provide fuel savings of 10-40% over a similarly sized internal combustion engine (ICE) powertrain. The savings come from eliminating the power lost through complex transmissions and relatively inefficient hydraulic systems.

Electrifying 1 "medium-sized" tractor with an EV reduces carbon emissions by as much as replacing 45 cars, according to Gridtractor. The company estimates farms can save 55-75% on fuel costs by going electric, plus pick up additional savings by supplying stored power to irrigation pumps and the grid.

"We estimate that on top of the field savings, farmers can save 15% for smart charging and Vehicle-to-Load/Vehicle-to-Grid applications, for a total of 90% cost savings that will be supplemented by lower maintenance and repair costs," says Gridtractor CEO David Meyers in a statement.

University of Kentucky ag engineer Joe Dvorak, whose research involves battery technology and electric propulsion, says the efficiency of an electric motor is multi-pronged.

"There are only a handful of moving parts in an electric motor, and their life expectancy is far superior to internal combustion engines," he says. "While electric motors for in-field farm use have to be designed to resist vibration, temperature fluctuations, and dust and water infiltration, think of all the electric motors in a farm shop — fans, drill presses, compressor motors — many of those are 30-50 years old and are still running."

In addition, electric motors provide significant amounts of instant torque and, with the proper motor controls, don't require a heavy, complicated transmission to operate at different loads and speeds.

Dvorak says electrified farm equipment as it is being developed also offers reduced maintenance because modern battery packs and motors are custom- designed and programmed for their application at the factory.

"Electric motors don't break that often, so there won't be many service calls," he adds.

3. Labor Shortage

The third driver of electrified farm equipment development is the continuing shortage of labor on farms of all sizes. This driver is met by the trend toward autonomous farm vehicles that are increasingly being powered by batteries.

Praveen Penmetsa, CEO of California-based Monarch Tractors, the maker of the first fully electric, driver-optional farm tractor, says the autonomous nature of his company's offering is aimed directly at farm labor challenges.

"We can use one driver to control 6-8 tractors, saving labor and freeing up personnel for other duties on the farm," Penmetsa explains.

"At the same time, our digitized platform is capable of collecting data in the field to automatically generate time-consuming regulatory reports and provide seed-to-table traceability of produce.

"This capability allows buyers of high-value crops to monitor crop development throughout the season without visiting the farm. It also allows growers to verify to consumers the farm practices in use throughout the growing season."

Filling the Need

An intersection of economic and political pressure is driving the current fledgling electrified tractor industry. But while the electric motor provides the above-mentioned advantages over traditional ICE powertrain design, many serious challenges to immediate widespread adoption of EV technology exist.

Ag Equipment Intelligence's surveys of North American farmers in February 2022 show a significant number of producers are reluctant to embrace EV technology. According to the 2022 survey data, top reasons for their hesitation include:

- Initial equipment costs.
- Lack of charging infrastructure.
- Run time concerns and lengthy charging time requirements.
- Distrust of "unproven" EV technology on the farm.

Dongoski says farmers will continue to look for technologies that make their jobs easier, more profitable and less risky. Electric tractor manufacturers like Monarch Tractor and Solectrac will need to prove their electric technology measures up to — and surpasses — the capabilities of traditional diesel-powered equipment to convince leery customers. But it seems the technological genie spawned by the automotive industry's shift toward EV is out of the bottle and making farm visits.

► **Most Realistic Applications of EV Technology on the Farm**

May 2022 | https://www.farm-equipment.com/articles/20414

Ag Equipment Intelligence ranks the likelihood of 10 farm applications going electric in the next 5 years.

The move to EV technology on the farm has begun as smaller electric tractors go to work in vineyards and specialty crops in North America and Europe. Based on existing technology and insights provided by equipment manufacturers and dealers, the *Ag Equipment Intelligence* 2022 report provided this 5-year outlook on which battery-powered equipment might become commonplace on farms based on a likelihood scale of 1-10 (1 = Not Likely and 10 = Highly Likely).

Barn & Stall Cleaning/Material Handling — 10

The lack of exhaust noise and fumes make compact EV tractors in the 20-70 horsepower range ideal for indoor scraping and hauling duties. As electric lifts and actuators are developed, these tractors may well dominate such work in livestock barns, horse arenas and confined feeding operations.

Landscaping — 10

Major OEMs are developing electric backhoe tractors capable of front-end loader use as well as excavation. Duty cycles of these medium-size machines are likely to be quite sufficient to operate throughout a typical construction site day with intermittent use allowing for cooling and charging.

Rural Lifestyle Use — 10

In all but the heaviest mowing and lifting chores, EV tractors will likely see their highest adoption rates on acreages and small hobby farms. As on-site charging infrastructure is developed, owners will be able to charge their EVs with small to mid-size solar arrays or wind turbines, plus use the EV's battery storage as backup home and barn power through V2G technology.

ATV/Lawn Mowing — 10

Several ATV/utility vehicle manufacturers currently offer EV models capable of day-long use. Similarly, electric lawn mowers of various designs are bringing quiet, exhaust-free operation to residential and acreage maintenance chores.

Livestock Feeding — 10

EV tractors expected to account for nearly a quarter of the offerings by 2027 are sized to handle light feeding chores and forage hauling duties.

Mowing — 10

Current small-to-midsize electric tractors are capable of mowing chores with roughly half-day run times to allow for cooling or battery swaps. Such machines range from 50-70 horsepower equivalency and are capable of operating either electric implements or driving hydraulic PTO systems.

Spraying — 8

Application of crop protectants and nutrients on a smaller scale will be well within the capabilities of tractors envisioned to inhabit the marketplace over the next 5 years. Weight limitations may prevent the use of larger capacity sprayer tanks, but on smaller operations, EV tractors will serve well in this capacity.

Planting, Spraying & Sidedressing by Autonomous Tool Carriers — 7

Equipment currently under development for battery powered tool-carrier robots, which eliminate the tractor, show great promise to compete with traditional pull-behind implements, particularly if such lightweight machines are deployed in groups and served by automatic docking stations for battery swaps and recharge.

Field Crop/Forage Harvesting — 1

Like ground-engaging field work, combining and forage harvesting applications require long duty cycles at high loads which cannot be met in a cost-effective manner with current and foreseeable battery technology of the next 5 years.

Broad Acre Ground-Engaging Field Work — 1

While electrification of such applications is possible through efficient diesel-electric hybrid systems, expected improvements in battery technology over the period do not seem likely for fully battery-powered electric farm machinery adoption.

► **Weight, dawn-to-dusk demands pose challenges to electrifying farm vehicles**

Aug 2021 | https://energynews.us/2021/08/18/weight-dawn-to-dusk-demands-pose-challenges-to-electrifying-farm-vehicles/

Agricultural equipment manufacturers are developing electric and autonomous machines to replace today's diesel tractors and combines, but problems must be solved before widespread adoption.

The seeds are sown for the electrification of farming vehicles, but as major manufacturers begin to develop electric prototypes, they face major logistical challenges to replacing diesel-burning machines in the field.

"The critical piece of the pie for greater adoption of electric vehicles in farm settings is charging infrastructure, followed closely by durability and reliability issues," said Scott Miller, associate dean for industry partnerships at Ohio University's Russ College of Engineering and Technology. "Farmers will not abide things that they cannot fix quickly, cheaply and easily."

Modern agriculture depends on a fleet of heavy-duty vehicles and machinery, from pickup trucks and small utility vehicles to massive tractors and combines that can weigh from a few tons up to as much as 15 tons, plus attachments. All that weight, along with dawn-to-dusk workdays and multiple worksites, adds to the challenges of electrification.

"Today the reason why most agricultural machinery is [run by] diesel is because of the high power-to-weight ratios when we look at energy storage in the form of diesel fuel," said Scott Shearer, chair of the Department of Food, Agricultural and Biological Engineering at Ohio State University. Large equipment "can work all day without having to refill."

Although diesel power is dominant now, the market for electric vehicles in the construction, agriculture and mining industries could grow to $100 billion annually, according to analysts Peter Harrop and Michael Dent at IDTechEx, headquartered in England.

It's still unclear precisely what mix of incentives, regulations and market forces might drive the transition to electric farm equipment, but countries will need to address the sector in order to achieve emissions reductions on a large enough scale to avert worst-case climate change scenarios this century.

The Intergovernmental Panel on Climate Change's latest report, released on Aug. 9, underscores the need for immediate steps to cut greenhouse gas emissions. Agriculture accounted for about 5% of U.S. industrial energy consumption last year, according to the Energy Information Administration.

Technological innovation could also spur demand for electric vehicles on the farm. Small electric tractors could be particularly helpful for family farms in developing regions that still use non-mechanized methods for agriculture, according to an August 2021 report in the Journal of Energy Storage.

Larger companies that make farm vehicles generally sell to global markets. So developments in other regions will likely affect the range of product offerings worldwide.

Additionally, farmers in Ohio and elsewhere could be drawn to the idea of replacing diesel with on-site renewable power, particularly those who have already leased part of their land for solar or wind energy in order to boost income. As the costs of renewable energy and battery storage come down, electric vehicles could eventually lower energy costs for farms.

On the drawing board and in the field

Mindful of the clean energy transition, multiple companies already have been working on electric-powered prototypes.

John Deere's concept model tractors would allow autonomous operation, which increases efficiency and precision. Cable power could even eliminate the need for onboard batteries, so that an electric version need not weigh more than its fossil-fueled counterpart. A John Deere spokesperson declined to be interviewed for this article.

Japan-based Kubota also introduced concept models in January 2020. Like the Deere models, they would allow autonomous operation. And triangular track arrangements could minimize weight and adjust for height in the field. The company's concept tractor also featured an onboard solar battery.

California-based Solectrac already has been offering small 30- and 40-horsepower-equivalent tractors and farm utility vehicles. Other options for relatively small tractors come from Fendt, Rigitrac, Escorts and others. Meanwhile, almost all airborne drones are electric.

Solar power could benefit a range of agricultural machinery beyond charging tractors, according to an April 2021 report in the Journal of Cleaner Production.

"We're beginning to see some agricultural sprayers that are actually operated with photovoltaics," Shearer said. An autonomous weed-control robot from Swiss-based ecoRobotix aims to use 95% less herbicides, for example.

Research also is focusing on small electric ground-based autonomous vehicles for sensing the plant environment. But field navigation could still be tricky, Shearer said. Challenges include working through plant rows, such as picket-fence formations used in cornfields, and dealing with plant canopies.

Challenges ahead

But it's a big step to go from prototypes and limited applications to widespread adoption.

"Farm equipment may only get used a few weeks a year," and those periods of use often run "up to 15 hours a day for many days on end," Ohio University's Miller said. "It does a farm producer no good if the battery runs out in the middle of a 1,000-acre field."

If batteries provide only about 15% of the energy that a full tank of diesel does, "you're still going to have to stop six or seven times a day," to swap out batteries, Ohio State's Shearer said. With spring planting time at a premium, the opportunity cost for those stops' lost productive time could run into thousands of dollars.

Adding bigger batteries isn't the answer, either. The additional weight can compact soil more than existing equipment does. The result could be less room for young plants' roots to grow, said Dale Arnold, director of energy, utility and local government policy for the Ohio Farm Bureau Federation.

Compacted soil also can interfere with no-till methods that many farmers have been using, Arnold added. No-till farming leaves more organic material and nutrients in the soil. The practice also lets more water infiltrate the soil, resulting in less runoff and nutrient pollution.

The key is trying "to find that balance" that lets machinery do work efficiently, without adding more steps or hurting farm yields, Arnold said. Also, many farmers' fields aren't contiguous.

"There are times where a large piece of equipment — a large tractor or a combine or a large cultivator — might leave home base and might not return for several days or a couple of weeks, based on the complications and the activities there," Arnold said.

Arnold's own family still farms the Brown Township property in central Ohio that belonged to his grandfather. The family also acquired farms in Harrison Township and Union Township, he said. Typically, farm equipment would work on one farm property. Then it would travel to the next property and the next, before returning to home base days or weeks later. The cycle would repeat for the next necessary tasks.

"You're always in that rotational schedule," Arnold said. "Many farm families, that's what they do."

So, even if large electric farm equipment could run for a full day on a battery charge, it wouldn't necessarily return to home base at night. That situation would add to the costs and challenges of charging infrastructure. And more stations would be needed in any case, Arnold said, because lighter-weight pickups or other off-road utility vehicles also would need charging.

"The one key issue is going to be breakthroughs in battery technology," Shearer said. In his view, even an increase in battery power to half the energy delivered by the equivalent weight of diesel fuel could be "a game-changer."

In the meantime, registrations for Ford's first all-electric pickup truck opened in May with the introduction of the F-150 Lightning. Lordstown Motors' planned electric pickup truck also could be a big winner, Arnold

said, if the company manages to overcome financial problems. On Aug. 11, the company announced plans to begin limited production in September.

"We feel that's going to be a very competitive market," Arnold said, noting that almost every farmer has a pickup truck, as well as smaller utility vehicles.

Wi-Fi connectivity is an additional challenge. Autonomous navigation and controls, on-board diagnostics, and other equipment devices will "depend on good high-speed communications with base stations or the internet," Miller at Ohio University said. Manufacturers also will likely move toward more cloud-managed solutions and software-as-a-service business models, he added.

"As we know, rural broadband is a huge limiting factor for rural communities," Miller said, "so these sorts of models will take time to implement and may require creative partnerships with major tech companies to overcome these connectivity hurdles."

The Reimagine Appalachia coalition also has been calling for major upgrades to rural areas' broadband and electric infrastructure as part of a plan for transitioning away from dependence on coal and natural gas. The group is pushing for funds to come from federal infrastructure grants.

In the meantime, niche areas for smaller vehicles and equipment could expand more quickly. And manufacturers of larger equipment will refine and test prototypes to make sure they can perform as well in the field as they might on the drawing board.

A specific time frame for widespread adoption of electric vehicles on farms remains undefined. Climate advocates generally want emission cuts to come sooner, rather than later. And if the world indeed shifts to net-zero greenhouse gas emissions within the next few decades, equipment manufacturers will want to continue to meet farmers' needs.

Ultimately, "farmers are interested in tools that will help them increase yields and productivity," Miller said. "The upside, hopeful note is that these tools have the potential to transform the method and manner in which agricultural producers manage their lands and crops by increasing efficiency and using their limited resources as wisely as possible."

- **Could Electric Tractors Revolutionize Farming?**

Apr 2023 | https://www.smithsonianmag.com/innovation/could-electric-tractors-revolutionize-farming-180982012/

Driver-optional e-tractors promise to increase efficiency while cutting emissions. Monarch Tractor

A quiet revolution is rolling across American farms—and it's so hushed that you may have to strain your ears to hear it.

Although diesel tractors are practically synonymous with farming, green technology is reshaping the relationship between farmers and these workhorses—and perhaps the nature of agriculture altogether.

An emerging fleet of whisper-silent and emissions-free tractors promises to unhitch growers from the burdens of conventional farming, far beyond its reliance on fossil fuels. By harnessing electric vehicle (EV) and robotics technology, driver-optional e-tractors help scale efficiency in all aspects of field work—from seeding and weeding to harvest and equipment repair—and may clear the path to better labor, field and sustainability practices.

"People don't build that much in factories anymore. Machines do, and people are there to supervise them," says Mark Schwager, co-founder and president of San Francisco Bay Area-based Monarch Tractor, which recently debuted the first autonomous e-tractor. "That's how farming should be."

Electric tractors have their roots in Northern California, an agriculture- and tech-heavy region. Sonoma County-based Solectrac launched the first model in 2017 and, despite a slow start—the company sold about two dozen vehicles in its first four years—sales finally gained traction last year, helped by state grants and increased manufacturing capacity.

The development of e-tractors trails the EV industry, says Schwager, which commoditized the production of lithium-ion batteries, motors and power components. Monarch was founded in 2018, less than an hour away from Tesla's Fremont factory, allowing it to tap into the established manufacturing base.

Zero emissions is a key selling point of any plug-in vehicle. But with a diesel tractor spewing carbon and particulate volumes equal to that of 14 cars, replacing one with an electric version can have remarkably scaled impact, with no change in productivity, says Schwager.

The auto-sized battery can last up to 14 hours on a single 5.5-hour charge (Schwager notes that barns are generally equipped with 220-volt plugs), and it has a lifespan of 15 to 25 years depending on frequency of use. An optional cart for toting a spare battery allows for quick, in-field swaps during power-intensive operations.

Eliminating emissions is only part of the package. Equipped with sensory cameras and a fully digital interface, Monarch's debut model, the compact Mark-V, incorporates autonomous EV technology: The driver-optional tractor can be programmed for automated runs; guided remotely through fields and orchards to spray, disk or harrow; or follow workers as they move along a row of crops, carrying supplies or hauling a harvest.

In an industry plagued with labor shortages and a rapidly aging workforce, "it's going to fill jobs that can't be filled," says Schwager. Using the autonomous capabilities, for example, one person can control a fleet of tractors from a screen to oversee multiple tasks spread throughout a farm.

Automation could also help relieve workers from laboring in inclement conditions, he adds, and encourage growers to adopt greener practices. "If mowing runs aren't costing you anything, weeds need much less spraying."

The driver-optional tractor can be programmed for automated runs; guided remotely through fields and orchards to spray, disk or harrow; or follow workers as they move along a row of crops, carrying supplies or hauling a harvest. Monarch Tractor

Domenick Buck, director of coastal services at Coastal Vineyard Care Associates in Santa Barbara, recently added 18 of the e-tractors to his vineyard management company's fleet of 40 diesel engines. Although he's found the EV's weight capacity limited in towing wider and heavier implements, the fuel savings and automated features—including night-vision capabilities that allow fieldwork to continue past sunset—all help the bottom line, he says. And while the technology has induced worker concerns over job security, "at this point, it's not a replacement," he adds. "By allocating certain tasks, it supplements what we already have," helping to ease anxiety over the scarcity and rising cost of labor.

As an organic and biodynamic operation, "we're also mindful of our lasting [impacts] on a property," says Buck, "so we're excited about reducing our carbon footprint." And the reduced noise pollution is a bonus, he adds—instead of the roar and rumble of a diesel engine, "this thing just hums along."

With a base price of $89,000—more than double that of a conventional compact—the savings can come at a cost. Schwager notes, however, that California offers generous rebates that can drop the price down to or lower than that of a diesel tractor. Monarch is working with other states and the federal government on similar programs, although the timeline is still unclear.

Yet the switch to electric can still work for those on a budget. With a base price of $12,990, the Amiga, a robotic micro-tractor, offers small growers a big labor solution, one that can be scaled and tailored to accommodate a wide range of needs.

Developed by Farm-ng, a robotics technology company based in Watsonville, just south of Silicon Valley, the Amiga looks more moon rover than clover weeder as it zips along the rural landscape. The four-wheel platform comes with a telescoping dashboard, and it runs on swappable e-bike batteries that last up to eight hours per charge. Despite the size, the one-horsepower drivetrain can tow or haul a thousand-pound payload, and it also sports a host of autonomous and remote functions.

"We're reluctant to call it a tractor, because we're not trying to replace them," says business development director Nathan Dorn. "We're replacing work that's more precise and more difficult," and even venturing into new territory such as greenhouses and barns.

Expandable in width from 3 to 7.5 feet, the Amiga is designed for modularity. The weldable steel frame allows multiple configurations and user customization, and it accommodates add-ons such as a precision seeder, a three-point powerlifter and even a driver's seat. "It's a building block for farmers," says Dorn.

Autonomous functions include self-guided and remote navigation—Farm-ng is also developing a similar technology for guiding the Blue Ghost Lunar Lander to a precise location on the moon's surface—as well as "follow me" capabilities.

Combined with Amiga's open-source platform, it's a blank canvas for endless hacks, says Dorn. The camera can be used to inventory trees in an orchard or cows on a pasture, for example, or use visual clues to gauge crop ripeness. He envisions users developing, sharing and even monetizing creative software via the company's online app store, much like a smartphone.

Despite initial skepticism from his crew around the robotic addition, "I think we pretty much have total buy-in at this point," says Ricardo Lopez, vegetable production manager of Rancho Soquel. Located in Santa Cruz County, the 17-acre organic and regenerative ranch grows a diverse range of crops—as many as 40 varieties in a given season—including tomatoes, salad greens and snap peas.

The farm, which includes grazing pastures and an orchard, has relied on mini-tractor-like rough terrain vehicles (RTVs) to transport supplies. But RTVs weigh heavily on the fields, so they're kept to the perimeters, requiring workers to carry tools, equipment and harvests by hand.

The compact and lightweight Amiga, on the other hand, treads lightly and "gives us flexibility around specific needs like sowing and in-bed cultivation," says Lopez. "And people are excited about not having to haul around crates anymore."

California rebates also apply to the Amiga, notes Dorn, and can reduce the cost by as much as 90 percent. Yet switching from a diesel tractor alone carries inherent savings: A full electric charge is cheaper than a tank of gas, and not having an engine eliminates maintenance costs such as particulate filter replacements, which, according to Schwager, can run nearly $3,000. (All tractors, however, require hydraulic maintenance.)

Both Monarch and Farm-ng openly support the right to repair—a seemingly rare position in the industry—and offer free, over-the-air support and updates to software and operating systems. Remote monitoring also alerts owners to issues and service needs, which, along with walk-through support, makes the technology less daunting, more accessible and more affordable.

"I've had robots in factories for my entire career and think it's unfair that farmers haven't had the same thing," says Schwager. "So I see great potential for technology to bring farming into the 21st century."

► Farming Goes Electric: The $234 Million Market Potential of Electric Farm Tractors

Jul 2023 | https://blog.marketresearch.com/farming-goes-electric-the-234-million-market-potential-of-electric-farm-tractors

The agricultural industry is undergoing a significant transition as it embraces the power of electric technology. Electric farm tractors, with their efficiency, sustainability, and potential cost savings, are becoming a key focus for farmers and industry experts.

According to BIS Research, the global electric farm tractors market is estimated to reach an impressive $234 million by 2028, from $98.7 million in 2022, with a CAGR of 14.06% during the forecast period 2023-2028, signifying a paradigm shift in modern farming practices.

This article explores the factors driving the market value to an exponential figure and the significant opportunities ahead for farmers and agribusinesses.

1. Advancements in Battery Technology Drive Growth of Electric Tractors

Advancements in battery technology are fueling the growth of electric tractors in the agricultural industry. Lithium-ion batteries, owing to their increased energy storage capacity and affordability, are leading the way. Innovations such as gold nanowires as electrodes and solid-state batteries offer improved performance, safety, and durability.

Moreover, emerging battery chemistries show promise for electric tractors, such as sodium-ion batteries and sodium-sulfur batteries.

In 2023, the market expects breakthroughs in lithium iron phosphate cathodes, silicon-based anodes, and the commercialization of solid-state batteries. The continuous progress in battery technology is essential for achieving lower costs, faster charging, and longer driving ranges, thereby driving the adoption of electric tractors.

2. Enhanced Operations with 5G Network and LoRaWAN

The implementation of 5G networks is expected to enable faster data rates, supporting machine-to-machine communication and Internet of Things (IoT) applications in agriculture. It is estimated that improved rural 5G coverage can boost long-term GDP in the agriculture sector by up to 1.8%.

With 5G, large-scale farms can leverage centralized data aggregation, real-time monitoring, and predictive analytics to enhance productivity and efficiency. Moreover, the high bandwidth and low latency of 5G facilitate the transmission of high-quality video data and enable autonomous vehicles such as tractors to exchange large amounts of data.

Meanwhile, long range wide area network (LoRaWAN) provides a low-power, long-range wireless communication protocol for tractors, enabling real-time monitoring of performance, precision agriculture practices, and remote control of tractor parameters.

3. Increasing Role of Climate-Smart Agriculture Practices

Electric farm tractors produce zero direct emissions during operation, promoting climate-smart agriculture practices. By integrating renewable energy sources, such as solar or wind power, farmers can further reduce their reliance on fossil fuels for energy generation in vehicles.

Moreover, the integration of electric tractors with precision agriculture technologies would allow for precise and efficient application of inputs, minimizing waste and improving resource management. This would further result in increased productivity, reduced environmental impact, and improved resilience to climate variability.

4. Growing Adoption of Electric Vehicles

Governments worldwide, such as Norway, the U.S., and China, are introducing incentives and subsidies to bridge the price gap between EVs and conventional vehicles, thereby stimulating the initial adoption of electric light commercial vehicles.

In the agricultural sector, the push toward electric farm tractors is being driven by concerns over atmospheric pollution caused by combustion engine tractors. Governments in regions such as the U.S. and the European Union have launched programs and initiatives to support the development of public charging infrastructure, ensuring convenient and affordable access to charging stations as the number of EVs increases.

Moreover, according to the International Energy Agency (IEA), electric tractors may represent around 35% of all tractor sales in India and approximately 20% of total tractor sales in China by 2040. These estimates assume that electric tractors will become financially competitive with traditional tractors in the near future.

Financial grants and tax exemptions are provided to charging station operators and construction projects, which are expected to fuel the demand for electric farm tractors, contributing to the growth of the market in the forecast period.

5. Growing Compatibility with Other Technologies

Electric farm tractors are getting increasingly compatible with advanced technologies, such as GPS guidance systems, variable-rate technology, automatic steering systems, and telematics. This compatibility would allow for precise field mapping, optimized seed planting and fertilizer application, autonomous navigation, and remote monitoring and control.

By integrating these technologies, electric tractors can enhance efficiency, productivity, and safety in modern farming practices. They enable data-driven decision-making, reduce costs, and optimize energy consumption.

Conclusion

The positive public perception of sustainable farming practices, along with the increasing demand for organic and locally sourced produce, would provide an additional incentive for farmers to transition to electric farm tractors. Electric tractors would further enable farmers to align their operations with consumer preferences, gaining a competitive edge in the market.

- **Electric Farm Tractor Market**

Jun 2023 | https://www.researchandmarkets.com/reports/5522545/electric-farm-tractor-market-a-global-and?utm_source=CI&utm_medium=PressRelease&utm_code=j69jc7&utm_campaign=1861455+-+Global+Electric+Farm+Tractor+Market+Report+2023%3a+Sector+is+Expected+to+Reach+%24234+Million+by+2028+at+a+CAGR+of+14.06%25&utm_exec=jamu273prd

The electric farm tractor market was valued at $98.7 million in 2022 and is expected to reach $234.0 million by 2028, growing at a CAGR of 14.06% between 2023 and 2028. The electric farm tractor market is driven by several factors, including the surging demand for sustainable agriculture practices from the agriculture industry, electrification and automation of agriculture machinery, and energy storage systems. In recent years, electric farm tractor has registered an exponential surge in interest among farmers, manufacturers, and researchers from the agriculture industry, with sales of electric vehicles (EVs) reaching record heights.

Market Introduction

The electric farm tractor market is an emerging sector within the agricultural industry that focuses on the development and adoption of electric-powered tractors for various farming operations. Electric farm

tractors are designed to replace conventional diesel or gasoline-powered tractors, offering numerous advantages such as reduced carbon emissions, lower operating costs, and quieter operation. Electric tractors utilize electric motors and batteries to power their operations, eliminating the need for fossil fuels. These tractors can be charged through various methods, including grid electricity, renewable energy sources such as solar or wind power, or even portable generators. The use of electric power in farming machinery aligns with the global trend toward sustainability and reducing greenhouse gas emissions. Key benefits of electric farm tractors include environmental sustainability, operational efficiency, reduced operating costs, noise reduction, government incentives, and others.

Industrial Impact

The electric farm tractor market is still in its early stages but has been experiencing significant growth and technological advancements in recent years. The market is driven by increasing environmental concerns, stricter emissions regulations, and the desire for sustainable farming practices. However, challenges such as limited battery range, longer charging times, and higher upfront costs compared to conventional tractors need to be addressed to accelerate adoption. Major agricultural machinery manufacturers, as well as startups, are investing in research and development to bring more efficient and affordable electric tractors to the market. Collaborations with battery manufacturers and advancements in battery technology are expected to address the range and charging limitations of electric tractors, further driving the market growth.

The electric farm tractor market is anticipated to expand as farmers recognize the long-term benefits of electric tractors and the government continues to support sustainable agricultural practices. The growth of the market is expected to be influenced by factors such as advancements in battery technology, charging infrastructure development, and the overall cost competitiveness of electric tractors compared to their conventional counterparts. In addition, battery technology is a critical area of focus for electric farm tractors. Advances in battery chemistry, energy density, and durability have resulted in improved performance and longer operating ranges. Lithium-ion batteries are commonly used due to their high energy density and efficiency. However, ongoing research aims to develop next-generation battery systems, such as solid-state batteries, which offer even higher energy storage capacity and improved safety. These advancements are crucial for addressing the range limitations of electric tractors and reducing the time required for recharging.

Moreover, electric farm tractors can integrate with precision farming technologies, revolutionizing agricultural practices. These technologies include GPS guidance systems, sensors, and data analytics, enabling precise and targeted farming operations. Electric tractors equipped with precision farming capabilities can accurately perform tasks such as planting, fertilizing, spraying, and harvesting. This enhances productivity, minimizes resource wastage, and promotes sustainable farming practices. Electric farm tractors have seen advancements in autonomous technology, allowing them to operate without human intervention. Through the integration of sensors, cameras, and artificial intelligence algorithms, these tractors can navigate fields, detect obstacles, and perform tasks autonomously. Autonomous electric tractors offer benefits such as improved efficiency, reduced labor requirements, and the ability to operate 24/7. They can also be coordinated with other autonomous farming equipment, enabling synchronized and optimized operations.

Market Segmentation

Segmentation 1: by Application

Light-Duty Tractor Continues its Dominance as the Leading Application Segment

The electric farm tractor market is led by light-duty applications, with a 50.98% share in 2022. The major demand for light-duty electric farm tractors is owing to their low curb weight, better battery performance, and low cost as compared to heavy-duty tractors, which attracts the farmers toward these tractors.

Light-duty electric farm tractors produce zero tailpipe emissions, helping to improve air quality and reduce greenhouse gas emissions. Government incentives and regulations play a crucial role in driving the demand for light-duty electric farm tractors. Many governments worldwide are implementing policies and incentives to promote the adoption of electric vehicles, including farm tractors. These incentives often come in the form of tax credits, grants, subsidies, or favorable financing options. Such support encourages farmers to invest in electric tractors by offsetting the higher upfront costs and making them more financially viable. In addition, stricter emissions regulations on conventional diesel-powered equipment in some regions are pushing farmers to seek electric alternatives to comply with environmental standards. Another significant factor contributing to the demand for light-duty electric farm tractors is the potential cost savings they offer in the long run. While electric tractors may have a higher initial purchase cost compared to conventional tractors, they tend to have lower operating and maintenance expenses.

Segmentation 2: by Mode of Operation

Manual Mode of Operation Witness the Highest Market Share in 2022

The manual segment accounted for the largest share of the electric farm tractor market in the year 2022 since the farmers are yet to be aware and technically skilled in autonomous technology, and it is expected to remain the same during the forecast period. The demand for manual electric farm tractors is influenced by several factors that make them appealing to certain farmers and agricultural operations. One significant factor is affordability. Manual electric farm tractors generally have lower upfront costs compared to their autonomous or robotic counterparts. This makes them more accessible to farmers with limited budgets, especially small and medium-sized farms. Farmers who recognize the benefits of electric tractors but do not require advanced automation may opt for manual electric tractors as a cost-effective solution that still provides the advantages of electric power.

Flexibility and control are additional factors driving the demand for manual electric farm tractors. Farmers have a higher degree of control and flexibility with these tractors, as they can manually operate and control them according to their specific needs. This allows farmers to adapt to the varying conditions of their fields and customize their farming operations accordingly.

The autonomous segment is anticipated to witness the highest growth rate during the forecast period 2023-2028. This is mainly due to the growing implementation and integration of digital and automation technologies in agricultural machinery.

Segmentation 3: by Drivetrain Technology

Battery Electric Witness Highest Market Share between 2023 and 2028

The global electric farm tractor market is estimated to be led by battery-electric drivetrains, with a share of 87.5% in 2022, owing to the growing demand for battery-operated electric farm tractors from light and medium-duty applications.

In addition, battery electric farm tractors can provide long-term cost savings. Although it has a higher upfront purchase cost compared to conventional tractors, it has lower operating and maintenance expenses. Electric farm tractors have fewer moving parts, resulting in reduced maintenance requirements and costs

associated with engine oil changes, fuel filters, and exhaust systems. Moreover, electricity is generally cheaper than diesel or gasoline, leading to lower operating costs over time. These cost-saving benefits make battery electric tractors financially attractive to farmers seeking to optimize their operational expenses and achieve long-term financial sustainability.

Moreover, governments worldwide are implementing policies to incentivize the adoption of electric vehicles, including farm tractors. This includes tax credits, grants, subsidies, and favorable financing options, which make battery electric tractors more affordable for farmers.

Segmentation 4: by Region

North America dominated the electric farm tractor market in 2022 and is anticipated to uphold its dominance throughout the forecast period. The growth in the market is majorly driven by the increasing research and development activities and large-scale adoption of electric farm tractors. Furthermore, the average land sizes in North America are huge compared to other regions such as the Asia-Pacific. Thus, farmers in the U.S. and Canada have massive revenues, which they could invest in technology. On the other hand, in developing countries, due to smaller farm sizes and overpopulation, farmers generate fewer profit margins, which are eventually redeployed into the operations, limiting any possibilities of investments. Also the ongoing trend for automation is also expected to have a significant impact on market growth.

Based on region, Asia-Pacific is expected to register the highest growth rate during the forecast period 2023-2028. This is due to ongoing efforts to digitize and electrify every industry, which will also benefit the electric farm tractor sector. Apart from this, the regional governments are enacting technology-friendly policies, which are expected to further have a significant impact on the market.

Recent Developments in the Global Electric Farm Tractor Market

In April 2023, Ideanomics's subsidiary named, Solectrac, added new products to its product category of e25 electric tractors. The new product has the feature of the hydrostatic transmission, a mid-PTO, and independent PTO operation and is named e25H. It will be available for sale by the 2nd quarter of 2023.

In December 2022, Monarch Tractor launched the electric tractor founder series named MK-V. It is the first commercially developed electric and driver-optional smart tractor. It combines technologies such as electrification, automation, and data analysis.

Demand - Drivers and Limitations

Market Demand Drivers:

Rising Awareness toward Sustainable Practices in Agriculture

Agriculture is a vast energy-intensive sector; it converts energy into food. Sustainable agriculture refers to farming practices that focus on producing food while minimizing the negative impact on the environment and preserving natural resources for future generations. In recent years, there has been a significant rise in awareness toward sustainable agriculture practices, with governments and farmers alike taking steps to reduce their environmental footprint. Governments around the world have recognized the need for sustainable agriculture practices and have taken various initiatives to promote them. For instance, the European Union has set a goal to reduce greenhouse gas emissions from agriculture by at least 20% by 2020. The United States Department of Agriculture has also launched the Natural Resources Conservation Service, which provides farmers with technical and financial assistance to implement conservation practices on their farms.

Increased Farm Mechanization and Technology Adoption

Increased farm mechanization and technology adoption in agriculture has the potential to improve the efficiency, productivity, and sustainability of agricultural production. Farm mechanization and the adoption

of smart farming technologies in agriculture lead to increased efficiency in various farming operations, such as planting, harvesting, and processing. This can reduce labor requirements and improve the speed and accuracy of these tasks. In addition, mechanization and technology can also lead to increased productivity by enabling farmers to cultivate larger areas of land and produce more crops per unit of land. For example, using precision farming techniques, farmers can optimize crop yields by applying fertilizer and water in precise amounts and locations.

Favoring Policies toward Electric Vehicle Adoption

Various electric vehicle (EV) incentives have been introduced in key markets over the past decade, helping to stimulate a strong expansion of electric vehicle models. For electric vehicles to reach their full potential to combat climate change, the 2020s must be the decade of mass adoption of light electric vehicles. In addition, specific policy support and model extensions for the medium and heavy vehicle segments will be crucial to mitigate emissions and make progress toward climate targets. Significant tax incentives fuelled the initial adoption of electric light commercial vehicles (LDVs) and underpinned expansion in the EV manufacturing and battery industries. The measures - primarily purchase subsidies or vehicle purchase and registration tax rebates - were intended to reduce the price gap to conventional vehicles.

Increased Demand for Electrification from Agriculture Industry

Not only cars can be powered electrically, but also commercial vehicles such as tractors, buses, trucks, vans, or vehicles used in agriculture and the construction industry. The E models are more environmentally friendly, quieter, and more efficient than those with combustion engines. Heavy commercial vehicles such as trucks, tractors, vans, and others are responsible for nearly 25% of CO2 emissions across the globe. Most of these vehicles are still powered by fossil fuels, i.e., diesel. In addition, commercial vehicles need a lot of fuel - and thus consume significantly more diesel than a car. But fossil fuels such as oil are finite. They also cause enormous air pollution.

Market Challenges:

Inadequate Charging and Network Infrastructure and Battery Recycling Challenges

Two basic infrastructural requirements for an advanced farming ecosystem are access to electricity, the internet, and communication. Although many nations have been able to electrify both urban and rural setups, most of the developing and underdeveloped nations have not been doing so. Apart from this, many countries do not have internet access for the population, let alone the rural population. Rural areas typically have lower population density compared to urban areas, which means that there are fewer potential EV owners and less demand for charging infrastructure. As a result, building and operating charging stations in rural areas can be less financially viable.

In addition, building charging infrastructure in rural areas can be more expensive than in urban areas due to the higher cost of materials, labor, and equipment transport. This can be particularly challenging for charging stations that require grid connection, as the cost of extending the electrical grid to rural locations can be prohibitively expensive. Moreover, private companies may be less willing to invest in charging infrastructure in rural areas due to the lower potential return on investment compared to urban areas. This can result in a lack of funding for charging station development and maintenance.

High Initial Cost of Equipment

Electric farm tractors have a higher initial cost compared to traditional diesel tractors. This is because electric tractors use advanced technology such as electric motors, high-capacity batteries, and advanced power electronics. There are several factors attributed to the high initial cost of an electric tractor which includes battery technology, power electronics, limited production volume, charging infrastructure, and research & development cost. For instance, electric tractors rely on battery technology, which is still

relatively expensive. The cost of batteries can be a significant portion of the total cost of an electric tractor and account for around 25-40% of the total cost. Battery costs have been decreasing in recent years, but they remain a major factor in the overall cost of electric tractors.

Development of Alternative Engine Models

Alternative vehicles, such as hydrogen fuel cell vehicles and biofuel-powered vehicles, are emerging as potential challengers to electric vehicles. For example, hydrogen fuel cell tractors are a type of electric tractor that use hydrogen fuel cells to generate electricity instead of traditional batteries. The basic principle behind hydrogen fuel cell technology is to convert hydrogen gas and oxygen into water, generating electricity in the process. The electricity is then used to power an electric motor that drives the tractor. There are key factors that promote the development of alternative engine models. For instance, one of the biggest challenges facing electric vehicles is their limited range. While advances in battery technology have extended the range of electric vehicles, they still have a much shorter range than traditional gasoline-powered vehicles. By contrast, hydrogen fuel cell vehicles and some biofuel-powered vehicles have longer ranged, making them better suited for long-distance travel.

Limited Market Penetration Owing to Dominance of Conventional Tractors

The conventional tractor industry is dominated by a few key players, including John Deere, AGCO, CNH Industrial, and Kubota. These companies have established themselves as leaders in the market through decades of innovation, production, and marketing. One reason for their dominance is their ability to offer a wide range of products and services to customers. These companies have a strong network of dealers and service providers, allowing them to offer customers a full range of products and services, including financing, maintenance, and repair.

Another reason is their ability to invest in research and development to improve the performance and efficiency of their products. These companies have dedicated research and development teams that work to develop new technologies and products to meet the evolving needs of farmers. Finally, these companies have strong brand recognition and customer loyalty. Farmers often have long-standing relationships with their equipment suppliers and may be reluctant to switch to a new brand or technology.

Market Opportunities:

Integration of New/Advanced Technologies with Electric Farm Tractor

The integration of new technologies in electric farm tractors is an emerging opportunity in the agricultural industry. Tractors have come a long way from their early mechanical versions to now being highly sophisticated machines equipped with a range of advanced technologies. These advancements in technology have not only improved the efficiency of tractors but have also made them more user-friendly and environmentally friendly. One of the most significant developments in electric tractor technology has been the integration of precision farming technologies. Precision farming involves using data and technology to optimize crop production and increase efficiency. The integration of precision farming technologies in tractors has allowed farmers to collect and analyze data on factors such as soil moisture, crop yield, and weather conditions to make more informed decisions.

Opportunities in Developing Nations

Developing countries are facing several challenges in the agriculture sector, including the need for increased productivity, reduced environmental impact, and improved economic sustainability. The adoption of electric farm tractors in these countries can offer several opportunities to address these challenges. Electric farm tractors can offer several benefits that can improve productivity in developing countries. For instance, they require less maintenance than conventional tractors, which can reduce downtime and increase overall

productivity. They also have greater torque at low speeds, which can be beneficial for tasks such as plowing and tilling.

How can this report add value to an organization?

Product/Innovation Strategy: The product segment helps the reader understand the different types of electric farm tractors available for deployment and their potential globally. Moreover, the study provides the reader with a detailed understanding of the electric farm tractor market by application (light-duty tractor, medium-duty tractor, and heavy-duty tractor), mode of operation (manual and autonomous), and by drivetrain technology (battery electric and hybrid electric).

Growth/Marketing Strategy: The electric farm tractor market has seen major development by key players operating in the market, such as business expansion, product launch, partnership, collaboration, and joint venture. The favored strategy for the companies has been product development to strengthen their position in the electric farm tractor market.

Competitive Strategy: Key players in the electric farm tractor market analyzed and profiled in the study involve major electric farm tractor manufacturers. Moreover, a detailed competitive benchmarking of the players operating in the electric farm tractor market has been done to help the reader understand how players stack against each other, presenting a clear market landscape. Additionally, comprehensive competitive strategies such as partnerships, agreements, and collaborations will aid the reader in understanding the untapped revenue pockets in the market.

Key Market Players and Competition Synopsis

The companies that are profiled have been selected based on inputs gathered from primary experts and analyzing company coverage, product portfolio, and market penetration.

The top segment players which are offering manual electric farm tractors include manufacturers such as Solectrac (Ideanomics, Inc.), Monarch Tractor, Cellestial eMobility Private Limited, Kubota Corporation, Sonalika Group, Rigitrac Traktorenbau AG, Erisha Agritech, EOX Tractors, EVE S.r.l., and SABI AGRI, that capture around 58.8% of the presence in the market. Players in the autonomous electric farm tractor segment include Monarch Tractor, Ztractor, AutoNxt Automation, Amos Power, SABI AGRI, Autonomous Tractor Corporation, and CLAAS KGaA mbH, among others account for approximately 41.2% of the presence in the market.

Key Companies Profiled

- Solectrac (Ideanomics, Inc)
- Monarch Tractor
- Cellestial eMobility Private Limited
- Kubota Corporation
- Sonalika Group
- Rigitrac Traktorenbau AG
- Erisha Agritech
- Ztractor
- AutoNxt Automation
- Autonomous Tractor Corporation
- CLAAS KGaA mbH
- EOX Tractors (Formerly H2Trac)
- EVE Srl
- Amos Power
- SABI AGRI

► **Global market for electric tractors to grow to USD 319.23 million by 2032**

2022 | https://www.futurefarming.com/tech-in-focus/global-market-for-electric-tractors-to-grow-to-usd-319-23-million-by-2032/

According to a recently published research report by Fact.MR the global market for electric tractors at present is valued at USD 94.04 Million in 2022. The market is anticipated to grow to USD 319.23 million by the end of 2032.

Key driver of the global market for electric tractors is the need to find alternatives for fossil fuels, according to Fact.MR's report. The benefits of electric tractors, such as zero emissions and substantially lower fuel costs, will drive sales of electric tractors. Moreover, stringent regulations related to emissions, and renewable energy represent a reason to pursue e-drive solutions in the agricultural industry, according to the researchers.

Limited availability restrains growth

However, the limited availability of electric tractors will restrain the growth of the market over the forecast period. And then there are practical disadvantages, such as low speed, limitation of battery technology and low energy storage capacity.

Electric vehicle batteries are made up of combustible components like lithium, manganese, and polymers. When lithium is exposed to water, it becomes extremely reactive. As a result, there are worries about these batteries' performance and safety in extremely dry or moist settings, thus limiting future sales.

Lack of charging infrastructure

The researchers say most farmers prefer fossil fuel-based tractors owing to the easy availability of fossil fuels. Lack of charging infrastructure is a major challenge in developing countries that may deter the adoption of electric tractors.

Geographically, the global market for electric tractors is projected to be dominated by North America owing to the rising demand for compact tractors.

Asia-Pacific, spearheaded by India, is expected to grow at a significant rate in the global market for electric tractors over the near future. Owing to the major agricultural landscape Asian countries are anticipated to drive growth in this sector. The technological upgradation and government support in countries like India, China, and Indonesia are set to increase demand for electric tractors in the forecast years.

The Middle East & Africa and Latin America are expected to hold small shares in the global market, however, the sale of electric tractors is expected to grow at a significant pace over the studied period.

► **How smart farming and electrification is key to sustainability**

2019 | https://www.harting.com/US/en/topics/how-smart-farming-and-electrification-key-sustainability

GROW, GROW, GROW

The term "Smart Farming" sounds like a buzzword. However, it is extremely important for meeting long-term world food demand and sustainability in the Agriculture industry. Smart Farming utilizes digital technologies and next generation concepts to achieve the best crop yield that is environmentally responsible. Artificial intelligence and big data tracking sunlight, temperature, humidity, and other environmental factors are used to optimize planting, spraying, irrigating, and other farming elements.

Advances in data technologies and electrification will help achieve higher crop yields, sustainability, food traceability, and efficient use of water with pesticide and fertilizer reduction.

The United Nations 2019 Revision of World Population Prospects states the world's population is expected to increase by 2 billion people in the next 30 years, from 7.7 billion to 9.7 billion in 2050. Credence Research forecasts the electric tractor market value of $2.9 billion USD in 2027 from $640.3 million USD in 2020.

"Smart farming includes increasing productivity, maximizing operational efficiency, and minimize labor costs."

TRACTOR ELECTRIFICATION

Electric tractors, the workhorse of Smart Farming, is a transformative trend that includes the application of technology components including sensors, GPS, and machine vision systems to perform various agricultural tasks. Credence Research forecasts the electric tractor market value of $2.9 billion USD in 2027 from $640.3 million USD in 2020. It is expected to grow at a CAGR of over 24.1 % during the forecast period.

ENERGY EFFICIENCY

The National Rural Electric Cooperative Association (NRECA) published a report estimating electric tractor adoption could yield a 50 percent average reduction in energy use vs diesel fuel. The analysis noted additional savings can be amplified by the electrification of other farm vehicles unrelated to producing field crops including pickup trucks and hauling trucks, which also consume fossil fuels.

POWERING AUXILIARY EQUIPMENT

In non-electrified tractor models, engines use traditional mechanical and hydraulic power take off (PTO) for the attachments. Electric tractors provide a far more efficient means of transferring energy to intelligent ancillary devices that utilize electrical power for traction drives, electric servomotors, embedded computers, vision systems, and a wide range of sensors. The John Deere Exact Emerge™ row planting units are an example employing mechatronics, sensors and controls orchestrated by advanced automation and artificial intelligence (AI).

These electric units eliminate cumbersome hydraulics facilitating a more responsive, efficient, and reliable process. Featured at the 2021 Consumer Electronics Show, the highly automated 8RX Tractor and 60-foot, 24-row planter feature more than 300 sensors and 140 embedded controllers that process up to 15,000 measurements per second. These technologies allow the tractor to precisely plant over 700 corn seeds–or 2,800 soybean seeds at the optimal depth based on current soil conditions to improve crop yields.

SMART FARMING CONNECTORS

Smart Farming electrification requires a range of connectors for applications including high power, medium voltage, sensors, and data communications. These connections are plugged and unplugged frequently over the equipment's lifecycle. Reliable and robust components play a crucial role in customer satisfaction as well as reducing maintenance cost over the equipment lifecycle. Poorly designed connectors that degrade over time in harsh environments increase the frequency of failure and correlates to additional expenses for the farmer. Quality designed connectors fail much less often and are typically easier to repair.

Connectors must be designed and manufactured to meet the harsh farming environment including wide temperature ranges, high vibration, washdown requirements, and demanding weather conditions. HARTING has broad expertise, know-how, and products for high power, medium voltage, sensors, and data communication applications for a broad range of industries including computing, railroad, industrial machines, electric vehicles, and electric generation.

Electrification deployed with connectors and cables efficiently distributes power to all elements.

DATA COMMUNICATIONS

Modern farming equipment incorporates data intensive features, including 3D technology, that provides a bird's-eye view of the system. These technologies make autonomous driving and remote farming possible through a wide range of electronics built on reliable industrial & IoT digital communications. The vision of fully autonomous farming encompasses all facets of agriculture with the goal of almost going backward in time; down to the fundamental seed level to achieve the highest yields imaginable.

HARTING supports all forms of data communications that are the backbone of Smart Farming. HARTING is at the forefront of the most exciting new development, Single Pair Ethernet (SPE) 10BASE-T1: a two wire 10 Mbps Ethernet physical layer network technology under the IEEE 802.3cg specification. SPE leverages Internet Protocol (IP) communications common in the computing and Internet of Things (IoT) world to communicate data and information.

OEM RELATIONSHIP

Manufacturers achieve superior results in product design and implementation of electrified tractors and implements through working with a strong connector supplier. HARTING has 75 years of practical expertise when creating connectors that meet demanding requirements through proper materials, barrier layers, contact pressure, and structural mechanics in related industries including railroad, automotive, consumer electronics and computing. HARTING can meet any connectivity needs for the next generation Agriculture equipment. OEM assistance includes HARTING Customised Solutions (HCS) which helps design and manufacture tailor-made solutions and Corporate Technology Services (CTS) laboratory accredited to DIN EN ISO / IEC 17025: 2018 for tests on electromechanical components, fiber-optic and electronic transmission systems, geometries, and material properties, as well as for EMC tests for CE mark approval.

The future is smart farming, and HARTING connectors help power a greener, more sustainable world today and tomorrow.

- **How Off-Grid Solar-Powered Electrification Can Drive More Revenue for Agriculture**

May 2023 | https://www.powermag.com/how-off-grid-solar-powered-electrification-can-drive-more-revenue-for-agriculture/

As the U.S. pushes to reduce greenhouse gas emissions by 50% by 2030, reaching that goal will require effort from all industry sectors. While transportation, electricity production, industrial manufacturing, and heating and cooling generate the majority of U.S. emissions, addressing the 11% contributed by agriculture is also critical to mitigating climate change impacts.

One way the industry can help reduce emissions is by electrifying heavy-duty farming equipment such as tractors and trucks that traditionally run on diesel. Powering this equipment and other farming processes with solar helps further reduce the use of fossil fuels.

However, farming is a low-margin business, so adopting new technology must make economic sense for growers, ranchers, and forest landowners. With the rising annual prices of feed, fertilizer, pesticides, fuel and labor, modern farming has become a high-cost operation. Production expenses were forecast to increase by 5.1% in 2022, the greatest level farmers have ever experienced.

The rate of return on farming assets is projected at less than 3.5% in 2022, in contrast to 10% to 16% returns from 2010 to 2012. This means that farmers and ranchers are seeing smaller revenues or returns for the investments made in the cost of production, and in assets used to produce a farm product. All of this is making it more difficult for growers to turn a profit.

While electric equipment offers many cost-saving advantages to farmers and is becoming more affordable, with additional government and utility incentives available, infrastructure challenges remain one of the

biggest barriers to the widespread adoption of electric vehicles and equipment. Farms are often located near weak areas of the grid, and the expense of adding expanded utility lines to accommodate solar is simply too great for most growers. Therefore, off-grid solar options are key to fully realizing the emission and cost-reduction potential of electrification in agriculture.

Barriers to Electrification

Electrification can offer many benefits to the agricultural industry—but transitioning to any new type of technology poses challenges.

Charging vehicles with electricity is much less expensive than gas or diesel. The average price of diesel fuel increased from $3.25 per gallon to $4.99 per gallon in 2022. However, electricity prices are also high. U.S. industrial customers paid an average retail electricity rate of 7.26 cents per kilowatt-hour in 2021, the highest recorded since 1970.

Solar power can provide affordable electricity for farmers to power their vehicles and equipment while further reducing their carbon footprint. Commercial and industrial solar power now accounts for a third of solar power generation in the U.S. This is largely due to a 60% reduction in cost over the past decade and increasing government and utility incentives. Farmers can install rooftop solar on barns, sheds, and other buildings to provide long-term clean, affordable electricity to charge equipment or power energy-intensive processes such as processing, packaging, and chilling. In some areas, net-metering programs allow farmers to sell excess energy back to the grid to generate additional revenue. Ground-mount solar systems are another option for on- or off-grid power located close to loads.

While farms tend to be in sunny locations, solar solutions are still limited by grid line capacity, which must be adequate to handle the bi-directional energy flows both from the grid to the farm, and from the solar system to the grid. Many solar projects are limited in size because the utility line capacity of the grid in farm country simply cannot accommodate them. Rural farms are often located near the ends of utility distribution lines, and the electric grid is not simple or cheap to expand in those locations. Expanded or new utility lines can cost $1 million per mile or more, so the expense of adding more grid capacity to accommodate electric vehicle charging is often not feasible for farmers.

Electric vehicles used on farms, including autonomous vehicles like electric wheelbarrows, need to be located near or in the fields where they do work since they require frequent recharging during their operation. Driving or trucking the vehicles back to the barn each time they need to be recharged is cumbersome and inefficient and adds costs in labor, time, and fuel. Therefore, farmers need access to an affordable, convenient source of power to effectively electrify their equipment. An off-grid power source close to where equipment is used maximizes efficiency by avoiding wasted time and labor.

The Power of Off-Grid Solar

Newer technology offers greater flexibility with pop-up off-grid solar arrays with batteries and electric vehicle chargers that can be set up quickly and moved according to where workers need to recharge tractors and other field equipment. These solutions offer resiliency and scalability without costly construction and infrastructure upgrades that may be required for fixed solar installations.

Electric vehicles and off-grid solar powered charging can also help with labor costs. Labor is increasingly the first- or second-highest cost factor for farmers. The tension between the slim margins of farmers and the need to pay farm workers a living wage is a strong driver to reduce those labor hours and costs wherever possible. Electric vehicles can reduce labor costs by operating autonomously to make labor more efficient. A good example is the use of autonomous vehicles such as electric wheelbarrows that can help reduce the labor of repetitive tasks like harvesting grapes in a vineyard. Electric wheelbarrows charged with off-grid solar are much more efficient because they do not have to be trucked back to the barn at the end of day for recharging.

Federal and local incentives are available to provide help for farmers looking to make the transition to electric vehicles and install off-grid solar systems. The federal Rural Energy Assistance Program (REAP) offers clean energy grants and loans, which the Inflation Reduction Act (IRA) doubled to $500,000 for efficiency projects and $1 million for renewable energy systems. These incentives are stackable with local credits. For example, because California's agricultural industry is the fifth-largest contributor to the state's greenhouse gas emissions, electricity provider Central Coast Community Energy (3CE) offers local farmers rebates to help them transition to electrification.

Amid high production costs, electrification has the potential to help farmers reduce expenses, giving them a leg up in their ability to realize greater revenue and profits.

Reducing Emissions While Generating Revenue

Our ability to reduce U.S. agricultural emissions lies with farmers, ranchers and forest landowners, but the high cost of modern farming means that transitioning to electrification must make economic sense for these business owners that provide critical food sources to our nation.

Off-grid solar-powered electrification has the potential to save farmers thousands of dollars a year in electricity, fuel and labor costs, providing a quick payback on their investments. As farmers, ranchers and forest landowners continue to discover where electrification fits into their business operations, new off-grid technology will enable them to overcome barriers to widespread adoption and enable success through economic and environmental benefits.

- **Electrifying agriculture: how Canada's farm industry is starting to transition**

Jun 2021 | https://electricautonomy.ca/2021/06/26/electric-agricultural-vehicles/

Farm equipment is poised to undergo a revolution with manufacturers exploring electrification, automation and artificial intelligence and some farmers taking the chance to pioneer the new technologies

Editor's note: this story was updated to reflect machinery emissions as part of the agriculture sector, specifically.

On a quiet vineyard in southern California, a familiar sight meets the eye: grape vines gently coiled up in acres of trellis, plenty of sun, blue sky and a telltale sign of work being done as a dusty plume appears mid-field.

The dust cloud and near-perfect silence signals what makes Wente Vineyards nearly unique in the world: an all-electric, compact smart tractor made by local manufacturer Monarch Tractors.

Wente Vineyards is the test site for Monarch, a company looking to disrupt the agriculture industry by building an all-electric compact tractor with AI capabilities. Founded in 2018, Monarch has been developing its product for over two years. Now, with just a few months left to go in late-stage development, the company is preparing to send its first orders of electric tractors to customers around the world — including Canada.

"In Canada there is great opportunity for us," says Monarch co-founder and president, Mark Schwager. "Obviously the farming industry is huge and we have a solution that, I think, is applicable for any farm. We are excited to come to Canada and bring our technology there."

Schwager and his company have identified a key under-serviced demographic in the global transition to electrification: farmers. While Monarch is not the only company offering a version of an electric tractor, the fact that the start-up is demonstrating an active, early interest in getting their vehicle into the Canadian market speaks volumes about the potential impact for Canada and the need for more widespread education and incentives to transition.

Breadbasket of the world, behind in tech

Canadian farms supply food to hundreds of countries around the world and the industry is critical to the global supply chain. Renowned as "the breadbasket of the world," Canada's agricultural industry has been identified by the federal government as "one of the sectors with the highest economic growth potential."

Agriculture in Canada accounts for 6.7 per cent of national gross domestic profit and 12.5 per cent of national employment, according to the most recent StatsCan data from 2016. But with over 193,492 farms across Canada, the industry's machines also account for roughly 18 per cent per cent of agricultural emissions.

It's on the technology side — especially with tractor electrification — that Canada is falling short, though it's not for lack of interest.

"We have been thinking about electric tractors for quite some time," says Darrin Qualman, National Farmers Union director of climate crisis policy and action in an exclusive interview with Electric Autonomy Canada.

"It's different region to region because the scale of the machinery is a lot different. In a place where the machinery is smaller — tractors that are 200 horsepower or less — I think people are quite interested and open to electric tractors. [Elsewhere] farmers are buying tractors with hundreds and hundreds of horsepower and there is nothing available. There is just no path for that."

Strategies around the world

The problem of finding a machine to fit the size of job is not a problem unique to Canada. Other countries around the world grapple with farms that stretch over thousands of acres and require specialty equipment.

Unlike Canada though, other jurisdictions are actively exploring non-gas or non-diesel options, which prompted BIS Research to release a report entitled: Global Powered Agriculture Equipment Market. The report indicates trends in electrified farming equipment between 2020-2025, finding the "market is projected to grow from US$63.17 billion and 2,217.8 thousand units in the year 2019 to US$70.03 billion and 2,359.7 thousand units by 2025."

The report also revealed that Asia-Pacific region and Japan were among the leaders in electric powered farm equipment sales in 2019, with China and North America following.

What Monarch has an eye to achieve in Canada and elsewhere in the global farming community is to redefine the framework that determines what a farm is and to establish operational best practices.

Armed with a decade of manufacturing expertise, Schwager believes the future of farming lies in changing the paradigm of thinking about what a farm actually is in order to maximize efficiency, yield and profit.

"What's a great opportunity in farming is actually to apply manufacturing process and manufacturing approach because the farm is a factory for food," explains Schwager. "If we take that approach and apply manufacturing principles and technology…to farms and were able to produce even half of that productivity increase, we are going to be more than sufficient for the amount of food we need to feed the growing global population."

Will it work?

In the game of manufacturing, large farms already have an edge: they have existed for the entire history of the industry as self-contained, vertically integrated ecosystems. The food is harvested in the same spot it grows, which is the same spot it was planted.

And farmers are already comfortable and accustomed to running their own show: they select the crops; prepare the land; select the seeds and sow them; they irrigate, tend the growth, fertilize and harvest — and then they repeat the process over and over again.

The ingredients are nearly all there for farms to be a highly successful and profitable operation, save for a near complete absence of technological innovation — that is to say automation and "smart" software — over the last 50 years, according to Schwager.

"It hasn't been a focus of traditional tractor companies to electrify because there hasn't been any pressure to do so," says Schwager. "Because tractor companies have not really changed their products in 50 years there is no real advantage from upgrading to the newest tractor. The maintenance costs may be slightly lower, but you don't get any other capabilities on that tractor. What we are doing is completely changing that landscape and providing so many tools and so many technologies that are going to make farmers better at what they do. There is a real incentive for farmers to upgrade to our equipment."

Even with zero-emissions becoming the guiding principle of Canadian policy and a global pandemic underscoring exactly how fragile the global supply chain is, Qualman says there is still a lot of advancement needed before the idea of an all-electric farm is possible.

"There is kind of a disconnect between small and medium tractors, which are easily electrified with off the shelf parts. You just essentially scale-up what GM and Tesla are doing. And then the other end is the big combines; some of them are running 500-600 horsepower — and tractors almost as much. I just don't know how you scale-up that electric technology to get you that."

Qualman says what will likely end up being the catalyst for widespread change in the agricultural industry is what heavy-duty, long-haul trucks choose to do to lower their emissions. Will they find an electric solution or go with hydrogen technology?

"A lot of the same powertrains [in tractors] are in those big trucks and require about the same energy capacity," he says. "We assume however the long-haul truck sector goes that's the way the big tractor and combine machine sectors will go."

The economic argument

As with an industry contemplating a shift, there is always the inevitable moment when the ledgers are pulled out and the question is asked: is this feasible?

Qualman says right now, it's unlikely. Even if the right electric equipment was available to buy, the anticipated price and lack of purchase incentives across Canada puts it out of reach for most farmers who already shell out up to a million dollars for a new combine harvester. Often tractors can last 30 to 40 years and when it does come time for a replacement, customers are trying to get a break on cost, not add a premium for going electric.

"Not many people are going to be able to line up for those big pieces of electrified equipment," says Qualman. "I don't think the people who are my neighbours — they just don't see it as a possibility even in 10 years."

For Schwager the upfront costs are offset by the long-term gains. If an electric tractor is in operation for decades, the owners are going to see a positive return on their investment with savings in fuel and maintenance, savings in labour costs and increased usage efficiency with the "smart" features baked into the machine.

"With electrification we can significantly lower those costs," says Schwager. "You can change your approach to farming because you aren't anchored by the economics of labour and of fuel."

A case study

Where electric farming equipment does have an opportunity to put down roots in the industry is in small-to-medium-sized tractors, say both Schwager and Qualman, because the economic benefit at this level is best realized. This is the market share that newer manufacturers like Solectrac and Monarch and older guards like John Deere and AGCO are targeting as they make their first foray into the electrified world.

But what about the customer experience with those few electric tractors actually working in the fields?

While a large-scale study has yet to be performed on the industry as a whole, one Ontario farmer — perhaps the first electric tractor adopter in Canada — says his experience shows going green puts farms in the green.

"In Ontario with the price of electricity and the price of gas, I'm saving about 50 per cent," said Tony Neale in an interview with farms.com. Neale is the owner of Wheelbarrow Farm, a 10-acre property in Uxbridge, Ont., just outside of Toronto.

Neale bought his all-electric Solectrac eUtility tractor in August 2018 for around $54,000. Sick of (and from) his exhaust-spewing diesel tractor, Neale decided he wanted a cleaner, quieter and more efficient work vehicle for his farm, even if it meant a jump in cost.

Neale's interest in technological trends led him to the idea of an electric tractor and a Google search landed him on Solectrac's website. Shortly thereafter, he was flying to California to consult with Solectrac to help assemble the electric tractor — with only one moving motor part as opposed to over 300 in a gas-powered engine — just right for his farm.

"This tractor is proof that electric tractors can be commercially produced and used by different farmers," Neale said, also citing the added weight of the battery pack — a detractor in other vehicle types — is actually a benefit to farmers because it gives the tractor more traction. "We could see a day where we don't need traditional fossil fuels."

Nearly four years later, Neale's electric tractor continues to be used on his farm.

"It's beyond proof of concept," said Neale in an interview with the Toronto Star. "We're past that. This is proof of commercial viability."

The future of farming

For Qualman, Neale and Schwager, the conversation about electric farm equipment has gotten easier in the last two years — even if the farmers haven't actually tried out the technology themselves, they appreciate the possibilities a transition offers. Education about options is more widespread and word of mouth about success stories like Neale's in the tight-knit community makes a big impact.

Industry organizations around the world are increasingly pushing manufacturers for options and governments for purchase incentives, while trade shows offer opportunities for farmers to look at the machinery of the future. The obstacle that will be the most difficult hurdle for both manufacturers and farmers to overcome in the transition to electric is time.

"The thing that has the longest service life is a tractor. If my neighbour buys a new tractor now someone is going to be using that tractor 30, 40 years from now," says Qualman. "That's why it's so important to get these electric tractors options out there as soon as possible, because it's going to take 30, 40 or 50 years to turn over the machinery. It could take decades just to get half the equipment changed out. That's why you've got to get started."

- **Global Powered Agriculture Equipment Market**

2022 | https://bisresearch.com/industry-report/powered-agriculture-equipment-market-report.html

Powered Agriculture Equipment

The powered agriculture equipment market encompasses a wide array of solutions such as tractors, combines, planters, sprayers, and other equipment such as tilling equipment, haymaking equipment, and balers. Farmers across the globe are increasingly adopting powered agriculture equipment to improve yield, soil fertility, operational efficiency, and profitability.

The powered agriculture market includes agricultural machinery manufacturers that provide vertically integrated farm equipment solutions.

The growth of the powered agriculture equipment market has been considerably extensive. However, there is still a significant share of the population unaware of the numerable benefits of these equipment and the extent of government support to the agriculture industry. In the past two decades, next-generation agriculture techniques and technologies have also been adopted by farmers across the globe to increase crop yield, shrink wastage, and ensure food security.

Powered Agriculture Equipment Market Overview

The global powered agriculture market was valued at $57.39 billion in 2021, which is expected to grow with a CAGR of 5.02% and reach $73.32 billion by 2026.

Impact of COVID-19

As the COVID-19 pandemic forces countries to close their borders, the agricultural sectors are facing major challenges. Even in regions and countries that are unlikely to face food crisis, such as those in North America and Europe, there is also a lack of labor as new challenges keep unskilled workers out. Also, COVID-19 travel restrictions across countries have led to an immediate shortage of seasonal farm labor due to the COVID-19 pandemic. This has had a heavy impact, especially in the ongoing harvest season and the upcoming planting season across the world.

Market Segmentation

Powered Agriculture Equipment by Equipment Type

The powered agriculture equipment comprises a wide range of solutions such as tractors, sprayers, planters, combines, and other equipment such as balers and tilling equipment. Farm tractors account for the largest share in the market, followed by combine harvesters, planters, and sprayers, in that order in 2021. The adoption of powered agriculture equipment is increasing among farmers to improve yield, operational efficiency, soil fertility, and profitability.

Powered Agriculture Equipment by Application

In terms of volume, sowing and planting application is expected to display the fastest growth during the forecast period, reaching a volume of 523.05 thousand units by 2026. Due to COVID-19, the travel restrictions across countries have led to an immediate shortage of seasonal farm labor. This trend has led to a heavy impact, especially in the ongoing harvest season and the upcoming planting season across the world.

Powered Agriculture Equipment by Region

In 2021, Asia-Pacific and Japan led the global powered agriculture equipment market, with a large market concentration in India. Trends such as high population growth, increasing disposable incomes, and booming urbanization in the Asia-Pacific and Japan region have resulted in a robust evolution in the consumption patterns amongst the population of the region. Hence, farmers of the region are focusing on increasing crop yield and having an all-year-round supply of agricultural produce to meet the escalating demand.

Key Market Players and Competition Synopsis

Some of the key players operating in the market Kubota Corporation, AGCO Corporation, Deere & Company, CLAAS Group, CNH Industrial N.V., ISEKI & CO. Ltd., Robert Bosch GmbH, Mahindra & Mahindra Ltd., Trimble Inc., SDF Group, Parrot S.A., Harvest Automation, PrecisionHawk Inc., Tirth Agro Technology Private Limited, Kinze Manufacturing, Yanmar Holdings Co. Ltd., ZETOR Tractors., among others.

The companies that are profiled in the report have been selected based on the selective pool of players, primarily Tier-1 (holding 50-60% of the market), mid-segment players (comprising 30-40% share), and

small and emerging companies (holding the balance 10-20% share), based on various factors such as product portfolio, annual revenues, market penetration, research, and development initiatives, along with a domestic and international presence in the Powered Agriculture industry.

► **The Future of Electric Farm Equipment**

Apr 2023 | https://www.agweb.com/news/machinery/new-machinery/future-electric-farm-equipment

Battery-powered hand tools now own the fix-it market. Yard equipment has its cell sights set on suburbia. Farm country, however, requires a much higher threshold of reliability. That isn't slowing down the flood of new lithium-ion powered equipment now making its way to dealer lots. Just in the last year ag companies such as CNH, Caterpillar, Doosan Bobcat, John Deere, Komatsu, Yanmar and Volvo have released prototypes or plans for industrial-sized electric equipment.

Some companies such as Monarch Tractor are already trying to establish a toehold. Its MK-V tractors have been used in California wineries since 2020. The fully electric, autonomous tractors feature 10 hours of runtime, 70 peak hp, 40 hp continuous, and twice the torque of a comparable conventional tractor.

Monarch MK-V

"Electric tractors offer farmers significant reductions in fuel costs over the life of the machine when compared with a diesel-powered tractor of the same capacity," says CEO and co-founder Praveen Penmetsa.

Production is set to begin this year. Monarch also offers a battery swap cart to keep the tractor running and uses 90% fewer moving parts than a comparable diesel unit.

CNH Industrial has been collaborating with Monarch. In December 2022 it announced an electric tractor prototype, which will ultimately be a Case IH branded model also with autonomous capabilities.

"There's a power density as it relates to technology where it doesn't work on a 555-hp tractor with today's technology, but it certainly has a use case with the duty cycle needed up to 50, 70, or 80 hp," says Kurt Coffey, vice president of Case IH North America.

Coffey recognizes electric isn't the only option for manufacturers as numerous alternative propulsion platforms roll out across the industry.

"The jury's still out at this point," he says. "We have tractors that go out for four weeks and never come home and so what about charging infrastructure, battery technology and power density? If you're talking about a 70 hp Farmall that runs four hours a day, the technology fits and that's where you'll see us go in the near term."

"I'm not going to say that electrification doesn't have a place in agriculture, but right now, just from a pure physics perspective, not at the high-power levels," echoes John Deere's chief technology officer Jahmy Hindman.

He says Deere's findings also show electrification could be a solution for lower horsepower units of 100 hp and under.

"In relatively light-duty cycles, lithium-ion chemistry batteries can work," he says. "You can package enough energy into the tractor to make that work. As you get into higher power levels? The answer is no."

Electric Equipment Rolls Out

First Five Monarch MK-V Tractors Roll Off Production Line

Hon Hai Technology Group ("Foxconn") today announced the start of production in Ohio of the Monarch MK-V, the first fully electric, driver-optional, smart tractors, with the initial five tractors rolling off the production line for delivery to customers. In June 2022, Foxconn signed a contract manufacturing agreement

(CMA) with Zimeno Inc. D/B/A Monarch Tractor ("Monarch Tractor") to build Monarch Tractor's next-generation agricultural equipment and battery packs at the Foxconn Ohio facility.

CASE CONSTRUCTION:

580 EV Electric Backhoe Loader

CASE Construction Equipment introduces "Project Zeus" — the 580 EV (Electric Vehicle), the construction industry's first fully electric backhoe loader. The power and performance of the 580 EV is equivalent to other diesel-powered backhoes in the CASE product line and provides considerably lower daily operating costs while also producing zero emissions — a motivating factor for utility and government contractors incentivized to work with equipment that leverages alternative fuels and lowers emissions.

The 580 EV is powered by a 480-volt, 90-kilowatt-hour lithium-ion battery pack that can be charged by any 220-volt/three-phase connection. While applications will vary, each charge will support most common eight-hour workdays. The battery separately powers the drivetrain and hydraulic motors, resulting in hydraulic breakout forces equal to diesel-powered machines and improved performance during simultaneous loader and drivetrain operation.

CL36EV Electrified Compact Wheel Loader

The CL36EV compact wheel loader is designed to deliver all the benefits of electrification in a machine with a small footprint that will excel in applications such as supply yards, large-scale building renovations and construction where indoor operation may be required, and any other operation that may require less noise and no emissions. The dynamic compact loader will help simplify maintenance and lower lifetime total cost of ownership through the elimination of the diesel engine.

"A loader of this footprint, especially one used in yard applications where it stays there and has regular access to primary power, is the perfect application for electrification," says Andrew Dargatz, product manager, CASE Construction Equipment. "The CL36EV delivers the same power and performance as comparably sized diesel-powered loaders and can be matched with a full range of attachments for additional versatility."

The CL36EV is a 3.6 metric ton machine with a hinge pin height of over 10 feet. Additional product information and commercial availability at CASE dealers in North America for the CL36EV will be announced at a later date.

DOOSAN BOBCAT:

Bobcat T7X and S7X

The T7X and S7X are part of Doosan Bobcat's push to lead the compact equipment industry's charge to an all-electric, emissions-free future.

With the T7X and S7X all-electric loaders, operators can simultaneously power the drive, lift and tilt functions without the noticeable power lag that is common among diesel/hydraulic machines. Doosan Bobcat says operators can feel a distinct power increase over traditional loaders, with no performance tradeoffs when operating multiple functions at once.

With 50% fewer components, simple componentry, and 96% less fluid, the company expects to drastically reduce maintenance and simplify troubleshooting with all-electric loaders. Many non-hydraulic Bobcat attachments will work with the Bob-Tach™ system on the T7X and S7X. Bobcat is working on a new line of electric attachments.

Currently, the company is delivering its first units of the Bobcat T7X compact track loader to Sunbelt Rentals, Inc. and it has plans to expand its electric equipment offerings in the coming years.

CATERPILLAR

950 GC Medium Electric Wheel Loader
906 Electric Compact Wheel Loader
301.9 Mini Excavator
320 Medium Excavator

Announced in 2022, Caterpillar rolled out several battery electric machine prototypes including the 301.9 mini excavator, 320 medium excavator, 950 GC medium wheel loader and 906 compact wheel loader. The machines are powered by Caterpillar battery prototypes and include an onboard AC charger. The company also plans to offer an offboard DC fast charging option.

"Caterpillar is well positioned to help customers reach their sustainability goals, including lowering emissions on the job site," said Construction Industries Group President Tony Fassino. "It's important we meet customers on their sustainability journey today with a variety of solutions including machines that run on renewable fuels or technology that increases fuel efficiency, as well as supporting them into the future as we power our next generation of machines."

The Caterpillar-designed batteries in these machines will also be available to power other industrial applications. Built on proven Caterpillar technology, the lithium-ion battery range features a modular design that offers flexible configurations across multiple applications. The batteries are engineered to be scalable to industry and customer performance needs and maximize sustainability throughout their lifecycle, including recycling and reuse at the end of life.

The 301.9 and 906 are expected to be the first commercially available models.

JOHN DEERE

310 X-Tier Electric Backhoe

In January of 2021, John Deere, and National Grid, an electricity, natural gas, and clean energy delivery company serving more than 20 million people throughout the Northeast, announced they will joint test an electric backhoe concept. The John Deere developed, battery-powered, electric vehicle design – referred to as E-Power – will target the ease of operation and performance level of the diesel-powered, 100 HP 310L Backhoe. The design is intended to provide substantially lower daily operating costs, lower jobsite noise, enhanced machine reliability, and zero tailpipe emissions.

The testing period will enable National Grid to expand its use of electric equipment on jobsites, reaffirming its commitment to leading the industry in the use of clean and resilient energy solutions.

“National Grid is one of only two energy companies in the US to add electric backhoes to their fleets,” said Badar Khan, President, National Grid, US. “We are excited to work with John Deere to take an important step in electrifying our company vehicles, which could be revolutionary for our industry. Decarbonizing transportation remains a challenge in the journey to net zero and we’re hopeful that bringing on more electrified heavy-duty vehicles and equipment will help us make significant progress.”

John Deere is in early Phase I development of its electric backhoe. To learn more about the John Deere backhoe lineup, visit www.JohnDeere.com.

VOLVO

L20 Electric Wheel Loader
L25 Electric Wheel Loader

Volvo Construction Equipment has upgraded its zero-emissions, low-noise L20 and L25 Electric compact wheel loader just as deliveries are starting in North America, meaning customers will get the new versions of the machines with enhanced uptime, versatility and operator comfort.

The updates include increasing the maximum speed to 12.4 mph, the option to fit a parallel linkage that delivers high breakout torque in various applications, additional operator-friendly features, and improved charging.

"As the first commercially available fully electric wheel loaders on the market, the L25 Electric and L20 Electric were already unique. These upgrades take them to another level with improved comfort, productivity and uptime," said Lars Arnold, electromobility product manager, Volvo CE.

The L25 Electric compact wheel loader was unveiled in 2019 and customer shipments began in Europe in the spring of 2020 and in North America this past summer. Both models offer zero exhaust emissions, lower noise, and comparable performance to diesel equivalents.

Recent upgrades include lower noise levels inside and outside the cab, thanks to a new hydraulic pump and the relocation of the main control valve from the cab to the front frame.

Additionally, operators in colder climates will appreciate the new programmable cab heater option, which allows them to easily choose the times and days of the week when they would like to arrive in a prewarmed and defrosted cab.

A new electric parking brake improves uptime with hill-hold functionality: a convenient automatic feature for operators working on inclines or rough terrain. And because the disc brake in the former model is now replaced by a spring-applied and hydraulic-released wet-disc brake, related maintenance requirements are removed, helping to cut costs and machine downtime.

The time it takes to achieve a full charge from zero is six hours with the 6 kW on-board charger if used with a 240V socket or level 2 public charging station. Speedier charging is available with optional off-board DC fast chargers at 11.5 kW or 17.3 kW. When this is combined with the newly launched electric machine management application, customers can further boost uptime by keeping track of charging status, battery level, and location to help manage the charging process more efficiently.

KOMATSU

PC210LCE Electric Excavator

To help customers reduce their carbon footprint and plan for implementing sustainable solutions through electrification, Komatsu unveils a 20-ton PC210LCE electric excavator.

The PC210LCE was created for construction businesses that need a high-performance machine while cutting fuel costs. Featuring lithium-ion battery technology developed by Proterra, the excavator has 451 kWh of battery capacity, designed for up to 8 hours of operating time.

Designed to reduce operator fatigue with less noise, exhaust emissions and zero engine vibration, the PC210LCE is ideal for use in urban areas and indoor environments. The low operating noise levels of the PC210LCE can allow for nighttime construction work both indoors and out.

Also just announced Komatsu and Moog have collaborated to build a fully electric compact wheel loader machine.

Moog's intelligent machine electrification system includes an electric traction motor, lift, tilt and steering electric cylinders, power electronics, system control computer, battery, and battery management system. The integrated software acts as the system's brain to connect and intelligently coordinate actions across the machine while the all-electric actuators and motors provide the muscle.

Komatsu/Moog Compact Wheel Loader

Komatsu provided the vehicle-level design and assembly, including structural configurations that take advantage of Moog's intelligent machine electrification system.

Agricultural Sensing & Monitoring

- **Pest Management Regulatory Agency Annual Report 2020–2021**

Feb 2022 | https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/corporate-plans-reports/annual-report-2020-2021.html

What are pesticides?

In general, pesticides are toxic chemicals intentionally released into the environment to control pests on crops, in homes and workplaces, and in industrial processes. These can include personal insect repellents, wood preservatives, and pool sanitizers. Pesticides also include biologicals (derived from natural sources such as bacteria, fungi, viruses, plants, animals and minerals) and devices.

There are more than 600 registered active ingredients in more than 7600 registered pesticide products in Canada.

Regulation of pesticides on the market

Once a pesticide has been registered, it becomes subject to a system of post-market risk management controls under the *Pest Control Products Act*. This includes re-evaluations and special reviews, compliance and enforcement activities, and reporting of health and environmental incidents.

Over the 10-year period between 2010 and 2020, the number of registered pest control products increased from approximately 6000 to over 7600. This represents an increase in post-market activity workload.

Sales of pest control products in Canada have increased from 101.1 million kg of active ingredients (kg a.i.) in 2014 to 121.3 million kg a.i. in 2018 (Figure 2).

In 2018, 71.1% of pesticide sales in Canada were agricultural sector products (Figure 3), whereas 24.3% were non-agricultural sector products, and 4.5% were domestic sector products.

Figure 3. Quantity of pesticides sold in Canada in 2018 by sector

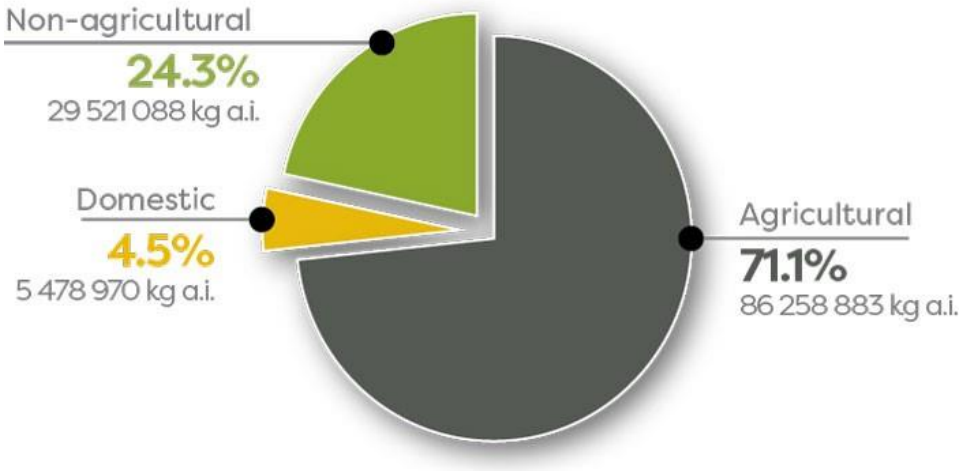


Figure 3 - Text

Description

Glyphosate remained the top active ingredient sold in Canada in 2018 (Table 1). Six of the top 10 active ingredients sold in 2018 had been among the top 10 selling active ingredients since 2014. These top 10 active ingredients accounted for 68.7% of all pesticides sold in Canada in 2018.

Table 1. Top 10 active ingredients sold in Canada in 2018

Active ingredient	Product type
Glyphosate	Herbicide
Available chlorine, present as sodium hypochlorite	Antimicrobial
Creosote	Antimicrobial
Prothioconazole	Fungicide
Glufosinate ammonium	Herbicide
Bromoxynil	Herbicide
MCPA	Herbicide

Surfactant blend	Other
Borates	Insecticides/Fungicides/Antimicrobial
2,4-D	Herbicide

- **Mycotoxins in grain – an overview of risks and solutions**

Sep 2022 | https://www.fossanalytics.com/en/news-articles/grain/mycotoxins-in-grain

Short read sums up why mycotoxins have always been a threat to health and agricultural production and the options to mitigate the risk.

Why fungi produce mycotoxins is an interesting topic in itself, but whatever the reason for their production, the presence of mycotoxins in grain presents a risk to the safety of food and feed products.

Vigilance is the therefore the word that comes to mind when considering the risk from mycotoxins to the grain supply chain. Testing regimes are required and protocols for the management of contaminated grain must be strictly followed to prevent the well-known health risks associated with mycotoxins.

When protocols fail
The concern is that all it takes is a slight deviation from these trusted protocols for significant, health-threatening problems to occur.

In Africa, aflatoxins found in maize and groundnuts is considered as the major cause of liver cancer, accounting for up to 40% of the cases. A major cause is that food shortages lead farmers to harvest their maize too early, with the immature grain being more susceptible to fungal infection. Other reasons are that the contaminated maize is not managed according to good agricultural praxis (GAP) and incorrect drying.

All it takes are a few weak spots in the supply chain to allow food safety risk to occur.

Are mycotoxins such a big problem?
The short answer is yes – mycotoxins are a persistent problem that change year by year and that depends very much on weather and the agricultural and manufacturing practice. What's more, once present, mycotoxins cannot be removed from the supply chain.

There are many studies that have tried to estimate the extent of mycotoxin contamination in global food crops supply. An often-cited report from the UN Food and Agricultural Organisation (FAO) stated that up to 25% of the global food crop was contaminated with mycotoxins. However, the origin of the data used to make this statement is largely unknown.

In a recent paper, published in the scientific journal Critical Reviews in Food Science and Nutrition, the authors discussed the validity of this statement. They found that current mycotoxin occurrence, that is samples with a level of mycotoxins above the EU limits, confirmed the initial FAO estimate of 25% contamination. Looking at data from BIOMIN(R), the authors conclude that detectable levels of mycotoxins may be found in up to 60-80% of the samples (Eskola, M., Kos, G., Elliott, C.T., Hajslova, J., Mayar, S. and Krska, R. 2020 Worldwide contamination of food-crops with mycotoxins: Validity of the widely cited FAO estimate of 25%. Critical Reviews in Food and Science and Nutrition 60:2773-2789).

In short, mycotoxins most be considered as a risk in any type of crops and relevant control points must be in place to ensure safe food and feed.

Risk management strategies
In terms of risk management, there are several areas where mycotoxins can be controlled within the supply chain.

Ultimately, prevention of fungal growth is the best strategy, and studies have shown that good agricultural praxis and biological control agents can be used to limit the growth of the fungi responsible for mycotoxins. A longer-term alternative is to breed cereal varieties that are more resistant to fungal contamination. In addition, crop rotation systems as defined in Codex Alimentarius: 'Code of Practice for the Prevention and Reduction of Mycotoxin Contamination in Cereals,' can reduce the chance of contamination by avoiding the planting of the same crop in the same field, for two consecutive seasons. This can help to reduce the inoculum in the field which may originate from post-harvest debris containing fungal spores.

The use of targeted fungicides is an obvious intervention that can reduce the risk of mycotoxins. However, growing consumer awareness and intolerance of the use of chemical agents in the production of grain crops could limit the efficacy of this control measure and could have an undesired backlash from consumers and media.

When considering crops for animal feed in the supply chain picture, there are absorbents that can be used to remove the mycotoxins as well as detoxification technologies such as enzymes which can break the mycotoxins down to harmless by-products.

Proactive management of the mycotoxin problem

Clearly, greater engagement with these proactive steps (GAP) to prevent or remove the food safety risk from the grain play an important part in reducing the threat. However, the strongest tool that we currently have at our disposal to manage the risk from mycotoxins is the systematic testing and rejection of contaminated grain.

Testing methodologies have improved significantly over the years. The speed with which mycotoxin analysis can be performed, combined with the sensitivity of the analysis, has greatly enhanced our ability to identify problems and remove them from the supply chain.

However, a changing climate potentially increasing and change the occurrence of mycotoxin contamination, all stakeholders in the supply chain will have to be more vigilant than ever.

In conclusion, we will have to use all the available tools at our disposal to ensure food safety across the grain supply chain.

- **Scientists expose the scale of mycotoxins in wheat problem**

Dec 2022 | https://www.foodsafetynews.com/2022/12/scientists-expose-scale-of-mycotoxins-in-wheat-problem/

Researchers have assessed the mycotoxin threat in European wheat and how it is changing. Fusarium mycotoxins were discovered in every European country.

A study by scientists from the University of Bath and the University of Exeter looked at Fusarium head blight (FHB) from 2010 to 2019. Findings were published in the journal Nature Food.

Mycotoxins occur when fungal pathogens infect crops and contaminate their products. They can harm human and animal health and impact farmers' income.

The European Food Safety Authority (EFSA) and Biomin mycotoxin survey data for the FHB mycotoxins deoxynivalenol (DON), fumonisin (FUM), zearalenone (ZEN), and T-2 were analyzed for a 10-year period.

Potential health impact

Neil Brown, from Bath University, said: "Contaminated crops and Fusarium toxins are always a worry, as they pose a significant threat to our health, especially as we only partially understand their effects on our wellbeing.

"But on top of these health concerns, we must remember that wheat is a hugely important global crop, so it's essential for us to maintain high yields along with safe food production — not least because of climate change, and now the war in Ukraine (the world's fourth largest exporter of wheat), are already impacting on wheat yields and grain prices."

Half of the wheat intended for human food in Europe contained DON, while in the United Kingdom, 70 percent was contaminated. However, 95 percent met the safety limits for DON concentration. The highest 10-year mean DON concentrations were in Hungary and the Netherlands.

DON was the most common FHB mycotoxin in European food and feed wheat. Occurrence and levels were lower in wheat for food than in the feed. This suggests that supply chain management, such as the postharvest downgrading of grain exceeding the limit for human consumption to animal feed, works to reduce DON entering the food stream for humans, said researchers.

DON occurrence was relatively stable in most countries over the decade. Sweden, Denmark, and the UK showed a high occurrence but at low concentrations. Scientists said this raises concerns about the health effects of chronic dietary exposure.

A quarter of food and 45 percent of feed wheat containing DON tested positive for other FHB mycotoxins. ZEN and T-2 were the most common co-contaminants.

"We don't understand the health implications of being exposed to multiple toxins at the same time, especially when that exposure is chronic. We're worried about growing levels of co-contamination and possible synergies between toxins," said Brown.

Estimated downgrading costs

The team put a price on the impact of Fusarium head blight mycotoxins by estimating the value lost by wheat being too contaminated with DON for human consumption.

"Across Europe, we estimate that 75 million tons of wheat (5 percent of food wheat) exceeded the limit allowed for human consumption between 2010 and 2019. Downgrading this to animal feed equates to a loss of around €3 billion ($3.2 billion) over the last 10 years," said Louise Johns, a Ph.D. student.

The scale of Fusarium head blight fluctuates from year-to-year but high disease years appear to be getting more severe.

"We don't know what's causing the increase in Fusarium mycotoxins, which is why we need more research, but we suspect that changes in farming such as soil preservation practices that provide a home for the Fusarium fungus and climate change such as warmer, more humid weather which favors the Fusarium fungus are playing an important role," said Johns.

Sarah Gurr, chair of food security at the University of Exeter, said: "We need to be vigilant in testing for mycotoxins in grain. We each eat around 66 kilograms of wheat flour per year – for example, in pasta and bread – and it's important for wheat to be protected from Fusarium infection so as to mitigate this risk."

- **The economic impact of mycotoxins**

Oct 2019 | https://www.poultryworld.net/health-nutrition/the-economic-impact-of-mycotoxins/

Mycotoxins are a significant problem worldwide causing notable direct or indirect economic losses in most countries. What measures can be taken to minimise these losses?

It has been estimated that about 25-50% of the world's food crops are affected by mycotoxins. The most economically important mycotoxins are aflatoxins, deoxynivalenol (DON) and zearalenone (ZEN). For growers, direct economic losses are related to reduced crop yields, and for livestock producers, reduced animal performance and increased losses due to disease. Reduced yields and decreased animal performance may be so widespread and undetectable in many instances. This is especially true when the level of infection and/or contamination is low. Disease symptoms are more apparent and losses can be catastrophic in individual cases. Indirect economic effects of mycotoxins are more difficult to quantify and probably as important as the direct effects.

Counting the cost of crop losses

Worldwide, substantial quantities of food grains are affected by mycotoxins each year. This includes 16 million tonnes of maize, 12 million tonnes of rice, 1.8 million tonnes of groundnuts, 378,000 tonnes of sorghum and millet, 3.7 million tonnes of copra and 2.3 million tonnes of soybeans. Estimates from sample data from the Food and Drug Administration (FDA) show that crop losses from mycotoxins (aflatoxin, fumonisin and DON) in maize, wheat and peanuts in the United States (US) average $ 932 million annually. Additionally, annual losses averaging $ 466 million were incurred by the US in efforts to prevent or reduce mycotoxin contamination (CAST, 2003). The study estimated livestock losses due to mycotoxins to be about $ 6 million. In 2003, world agriculture trade was valued at greater than $ 500 billion with 33% of this amount coming from developing countries including countries in Latin America and the Caribbean (FAO, 2006). In Brazil, private feed companies have undertaken measures to control levels of mycotoxins in animal feed since these toxins reduce the efficiency of livestock production. The cost of mycotoxin analyses is estimated to be about $ 55,900 in capital investment and between $ 0.02–$ 0.06 per tonne of feed per month. Brazil produced 35.3 million tonnes of maize in 2001-2002 of which 65% was used for animal feed.

Impact of rapid mycotoxin analyses

Paul Sundberg of the National Pork Board stated that swine producers do not recognise on-going losses from aflatoxin, although they may occur in localised production areas in severely affected crop years. Only a very small number of cases of aflatoxin toxicity in swine are reported in the US due to the existing food safety regulatory systems. The poultry industry now relies upon sampling of corn by feed mills, to keep the contamination within the levels stated by the FDA guidelines. The sampling is often part of the same integrated production and marketing operation. The rate of sampling by the feed mills varies greatly and is dependent on industry reports of the occurrence of aflatoxins in corn from specific locations in that year. For example, when corn industry reports aflatoxin contamination in specific states or when positive samples are found during routine sampling, the rate of sampling by the poultry industry is greatly increased in those areas. A large integrated turkey producer reported conducting 2,200 non-ELISA assays for aflatoxins, costing approximately $ 2.67 per test and 4,200 tests were also carried out for fumonisins, DON and ZEN using ELISA test kits at $ 7 per test. These tests were conducted in the company's laboratory which serves the feed mill and production facilities. The huge number of tests conducted were to assure the safety of approximately 400,000 tonnes of corn and were skewed to test a greater proportion of the locally bought southeast corn, than 'corn belt' corn.

Mycotoxin management strategies

The best practical way to control mycotoxin levels is to use rapid test kit systems for the analysis of mycotoxins in raw ingredients which are not yet in silos. Different rapid test kit systems are validated for different mycotoxins and commodities offering a very quick and effective way of raw material screening before they enter the feed mill. Once the levels are known, every feed mill can estimate the quality of its raw ingredients in terms of mycotoxin contamination and can effectively and more precisely (by dosage adjustment) apply feed additives during feed production.

Another strategy of mycotoxin risk management is to test for the presence of mycotoxins in finished feeds. This method has some advantages and disadvantages. Since each raw ingredient can bring its own mycotoxins into the finished feed, the most important advantage is that the presence of raw ingredients with a low inclusion rate (5-10%) which can still cause significant contamination of the finished feed but can be inadvertently overlooked if not tested, can be identified by testing the finished feed. The most important disadvantage is that analysis of finished feed takes quite a long time. So much so that the tested feed is likely to have been fed to the animals by the time the results from the analysis are known.

Storage mycotoxin contamination (ochratoxins, aflatoxins) can be prevented by keeping temperature and moisture content in silos low whilst aerating the grain regularly. In cases where perfect storage conditions cannot be guaranteed, the use of mould inhibitors is highly recommended. To mitigate the negative economic impact of mycotoxins on animal health, the application of specific feed additives (mycotoxin deactivators) is highly recommended. The Adisseo web application – Mycoman, informs the user about mycotoxin challenges and based on the challenge levels, calculates the necessary and effective dosage of the Adisseo mycotoxin deactivators product line. Mycoman is currently available for free online from Android Play Store (Google) and iOS (App store).

Author: Radka Borutova, Adisseo, France

- **Mycotoxin Feed Testing Global Market Report 2023**

Jul 2023 | https://www.reportlinker.com/p06479915/Mycotoxin-Feed-Testing-Global-Market-Report.html?utm_source=GNW

Summary

Major players in the mycotoxin feed testing market are ALS Limited, AsureQuality Limited, Bureau Veritas, Eurofins Scientific SE, Intertek Group plc, Mérieux NutriSciences Corporation, SGS SA, Symbio Laboratories, Bio-Check (UK) Ltd., Charm Sciences Inc., EMSL Analytical Inc., IEH Laboratories and Consulting Group LLC, Neogen Corporation, Premier Analytical Services Inc., and Romer Labs Division Holding GmbH.

The global mycotoxin feed testing market is expected to grow from $1.28 billion in 2022 to $1.37 billion in 2023 at a compound annual growth rate (CAGR) of 6.8%. The Russia-Ukraine war disrupted the chances of global economic recovery from the COVID-19 pandemic, at least in the short term. The war between these two countries has led to economic sanctions on multiple countries, a surge in commodity prices, and supply chain disruptions, causing inflation across goods and services and affecting many markets across the globe. The mycotoxin feed testing market is expected to reach $1.80 billion in 2027 at a CAGR of 7.2%.

The mycotoxin feed testing market includes revenues earned by testing for mycotoxins such as fumonisins, deoxynivalenol, and other mycotoxins present in food and animal feed such as dried fruits, apples, coffee beans, cocoa tea, herbal tea, fruit tea, and others.The market value includes the value of related goods sold by the service provider or included within the service offering.

Only goods and services traded between entities or sold to end consumers are included.

Mycotoxin feed testing refers to the process of analyzing food or feed samples for the presence and quantity of mycotoxins, which are naturally occurring toxic substances produced by fungi that can contaminate animal feed and cause health problems in livestock. The purpose of mycotoxin feed testing is to ensure the safety and quality of the feed, and ultimately, the health of the animals that consume it.

North America was the largest region in the mycotoxin feed testing market in 2022.Asia-Pacific is expected to be the fastest-growing region in the forecast period.

The regions covered in this report are Asia-Pacific, Western Europe, Eastern Europe, North America, South America, Middle East and Africa.

The main types of mycotoxin feed testing are aflatoxins, alternaria, cyclopiazonic acid, citrinin, fusarium toxins, ergot alkaloids, patulin, ochratoxins, sterigmatocystin, and others.Aflatoxins are a kind of toxin generated by a fungus found on agricultural products such as maize (corn), peanuts, cottonseed, and tree nuts.

They perform testing on cereals, seeds, seed products, forage and silage, and others, and use various technologies such as chromatography, immunoassay, lateral flow assay, spectroscopy, and others. They are used by various end-users such as food and beverages, animal feed, and pharmaceuticals.

The increase in incidences of food born illness is expected to propel the growth of mycotoxin feed testing going forward.Food-born illness refers to disease or sickness that is caused by the consumption of foods or beverages that are contaminated with pathogens or microorganisms.

Food-born illnesses are increasing due to the increasing use of commercial food services, new methods of producing and distributing food, new or re-emerging infectious foodborne agents, changes in diet, and others.Mycotoxin feed testing will reduce the chances of ingesting contaminated food and hence, reduce food-borne illnesses.

For instance, in May 2022, according to the report published by the World Health Organization (WHO), a Switzerland-based government agency responsible for international public health, 600 million individuals or around one in ten people around the globe become are suffering from food-born illness and 0.42 million people die every year. Therefore, the increase in incidences of food born illness is driving the growth of the mycotoxins feed testing market.

Technological advancements are a key trend gaining popularity in the mycotoxins feed testing market. Mycotoxin feed testing refers to the process of analyzing animal feed samples for the presence and quantity of mycotoxins, they are naturally occurring toxic substances produced by fungi that can contaminate animal feed and cause health problems in livestock.

The mycotoxin feed testing kits enable users to gain more assurance and check the quality of food or feed as well as protect them from illnesses. For instance, in September 2022, Ring Biotechnology Co Ltd., a China-based biotechnology company specializing in rapid food safety testing and animal disease diagnosis, launched the new iQuanti mycotoxins quantitative rapid test kit, it is a lateral flow immunoassays-based test kit used for the detection of the five major mycotoxins in cereal such as aflatoxin B1, zearalenone, fumonisin, T2-toxin, ochratoxin and vomitoxin. It can identify the main mycotoxins in 10 minutes following a simple specimen extraction.

In January 2021, Societe Generale de Surveillance SA (SGS SA), a Switzerland-based company that provides inspection, verification, testing, and certification services acquired SYNLAB Analytics & Services, for $ 616.58 million (550 million euros). This acquisition aims to strengthen SGS SA's global network in key strategic focus areas, SUCH AS environment, food, life sciences, and oil condition monitoring. SYNLAB International GmbH is a Germany-based laboratory and medical diagnostic services company, focused on human and veterinary testing, as well as environmental analysis.

The countries covered in the mycotoxin feed testing market report are Australia, Brazil, China, France, Germany, India, Indonesia, Japan, Russia, South Korea, UK, USA.

The market value is defined as the revenues that enterprises gain from the sale of goods and/or services within the specified market and geography through sales, grants, or donations in terms of the currency (in USD, unless otherwise specified).

The revenues for a specified geography are consumption values that are revenues generated by organizations in the specified geography within the market, irrespective of where they are produced. It does

not include revenues from resales along the supply chain, either further along the supply chain or as part of other products.

The mycotoxin feed testing market research report is one of a series of new reports that provides mycotoxin feed testing market statistics, including mycotoxin feed testing industry global market size, regional shares, competitors with a mycotoxin feed testing market share, detailed mycotoxin feed testing market segments, market trends and opportunities, and any further data you may need to thrive in the mycotoxin feed testing industry. This mycotoxin feed testing market research report delivers a complete perspective of everything you need, with an in-depth analysis of the current and future scenario of the industry.

- **MYCOTOXIN TESTING MARKET SIZE & SHARE ANALYSIS - GROWTH TRENDS & FORECASTS (2023 - 2028)**

2023 | https://www.mordorintelligence.com/industry-reports/mycotoxin-testing-market

Mycotoxin Testing Market Analysis

The global mycotoxin testing market is projected to grow at a CAGR of 11.7% during the forecast period.

The mycotoxin testing ensures that the products are carcinogenic-free, and complies with the International regulation standards. Mycotoxins are toxic chemical compounds produced by a fungus, which can lead to various diseases and even death.

Cereals and grains are the products that get affected by the fungus, during storage. Therefore, mycotoxin testing becomes necessary for such products, to eliminate the risk of health hazards.

Fusarium mycotoxins likely to hold a major portion of the global mycotoxin testing market share.

Impact of COVID-19 on the Market:

The distorting effect of the virus in the region was majorly attributed to bad health profiles and low immunity, majorly contributed by the prevalence of unhealthy eating habits and lack of physical activities practiced by consumers. Europeans are now expected to be extra conscious about their food choices, with more focus toward health-building supplements, functional foods, and juices. This depicts promising applications for food safety testing services in the future.

Despite no evidences being found on the spread of virus through food and its packaging, food manufacturers in the region are constantly looking for a double check, in terms of providing safe food to consumers.

Considering the possible contingencies of food manufacturers to offer virus-proof food products to consumers and gain a competitive edge over other market players, the demand for Mycotoxin testing may be moderately uplifted in 2020 and in the following years.

Mycotoxin Testing Industry Segmentation

The global mycotoxin testing market is segmented by technology into HPLC-based, LC-MS/MS-based, Immunoassay-based, and Other Technologies. By pathogen type into Aflatoxins, Ochratoxin A, Patulin, Fusarium Toxins, Other Mycotoxins. By application into beverages and foods. By geography, the scope includes North America, Europe, Asia-Pacific, South America, and Middle East & Africa.

Mycotoxin Testing Market Trends

This section covers the major market trends shaping the Mycotoxin Testing Market according to our research experts:

Immunoassay-based is the Fastest Growing Mycotoxin Testing Technology

ELISA (enzyme-linked immunosorbent assay) is one of the most popular immunologically-based methods used in test kits for the analysis of mycotoxins in foods and feeds. ELISA method for detection of mycotoxins has been used by a number of food safety manufacturers and has been available for a decade now. The method is based on the ability of a specific antibody to distinguish the three-dimensional structure of a specific mycotoxin.

ELISA mycotoxin tests are considered as high throughput assays with low sample volume requirements and often less sample extract clean-up procedures in comparison to the conventional methods, such as TLC and HPLC. ELISA detection method is reliable, rapid, specific, sensitive, easier, and portable for use in the field for the detection of mycotoxins in foods and feeds.

Europe Held the Highest Share in Mycotoxin Testing Market

Aflatoxin contamination of agricultural commodities poses considerable risk to human and livestock health and economic losses. Exposure of human to aflatoxin leads to several health-related conditions, including acute and chronic aflatoxicosis, immune suppression, liver cancer, liver cirrhosis, stunted growth in children, and many others. Aflatoxins are detected in several crops, especially in maize and groundnuts. Aflatoxin is the most important contaminant on the Rapid Alert System for Food and Feed (RASFF) of the European Union. In 2008, aflatoxins alone were responsible for almost 30% of all the notifications to the RASFF system (902 notifications). Fumonisins FB1 and FB2 have been found in rural areas of South Africa, in homegrown corn produced and consumed by the people living in those areas. Commercial corn-based human food products from retail outlets in several countries contain fumonisins

Mycotoxin Testing Industry Overview

Global mycotoxin testing market is highly competitive with the presence of few major players SGS S.A., Bureau Veritas S.A., Intertek Group Plc, Als Limited, Eurofins Scientific, Dts Laboratories, Ils Limited, Covance Inc., Silliker, Inc., and Asurequality Limited.

- **DSM World Mycotoxin Survey: Impact 2023**

Jan 2023 | https://www.poultryworld.net/health-nutrition/health/dsm-world-mycotoxin-survey-2023/

Mycotoxins continued to provide the cereals sector with considerable challenges last year as producers turned to cheaper products to manage risks.

The Covid pandemic affected logistics and availability of feed materials, and this coupled with increased input and energy costs caused by the war in Ukraine meant significantly higher costs for producers. As a result, some farmers turned to cheaper products to manage their mycotoxin risk.

Annelise Mueller, global product manager DSMhttps://www.dsm.com/anh/home.html and responsible for its annual survey, which has been running since 2004, said a total of 27,279 samples were taken last year with 122,240 analyses from 87 countries for 6 main mycotoxins (aflatoxins, zearalenones (ZEN), fumonisins (FUM), deoxynivalenols (DON), ochratoxins and T-2's)

Areas with extreme risk category

Ms Mueller said mycotoxin prevalence and risk last year was categorised as extreme in **China**, **South Asia** and **North America** with samples showing a total risk of more than 75%. The risk level expresses the percentage of samples testing positive for at least one mycotoxin above the threshold level in parts per billion (ppb).

For example, the total risk level in the China/Taiwan was 97% with FUM 93%, DON 84% and ZEN 82% being the most common mycotoxins found.

Risk above 50%

Samples from the Middle East and North Africa, Sub-Saharan and South Africa had total risk levels above the 50% threshold while levels were lower but still significant in Europe and Oceania.

European risk levels

DSM Animal Nutrition and Health mycotoxin risk managers Dr Wolfgang Markert and Sander Janssen, spoke of varying results across Europe from the nearly 9,000 samples taken. The European risk level of around 40% contained, for example some extremely high DON levels of 445,000ppb.

In all samples, DON was the most prevalent (46%), followed by ZEN (42%) and FUM (34%) although T-2 levels were significant at 34%. In corn, average levels of DON and ZEN were higher when compared to 2021 statistics.

…most concerning European statistics had come from Hungarian corn

Higher risk in southern & eastern Europe

In general, higher percentage of mycotoxins were found in southern and eastern Europe. For example, in Italian finished feed FUM levels were very high 99%, with the hot climate ensuring that FUM grew easily. ZEN and DOM were also highly prevalent, and a 42% Aflatoxin level was found. Aflatoxins can be transmitted from milk to humans.

Ukraine

FUM was also found in 80% of Turkish samples, with high levels of contamination, while in Ukraine a high volumes of ZEN contamination were found in wheat grains samples with levels of 48ppb – close to the risk for sensitive species, such as piglets and up to a maximum of 153ppb. Janssen and Markert said if farmers were to mix grains from Ukraine with finished feed, mycotoxin levels could be too high, so proper analysis and mitigation methods were needed.

Hungary

Markert pointed out that some of the most concerning European statistics had come from Hungarian corn (kernels), where levels across all 6 mycotoxins were relatively high (76% DON, 72% FUM, 40% T2, 37% ZEN, 33% OTA and 30% Afla).

Netherlands – risk to poultry

Turning to the Dutch results, the presenters said the Netherlands imported a lot of compound feed and the results showed 67% contamination with more than 1 mycotoxin and some high T-2 ppb figures which can be a specific risk to poultry.

Concerning for poultry producers in Middle East and Africa

Further afield, Janssen said samples in the Middle East and North Africa showed FUM mycotoxins were highly abundant and the prevalence of ZEN, FUM and especially DON and T-2 had increased, which was concerning for poultry producers. 100% of corn kernel samples were contaminated with at least 2 mycotoxins.

In sub-Saharan Africa, DON (67%) is the main risk, while ZEN and Afla abundance increased, while there were nearly 800 samples taken from South Africa, showing that nearly 70% had more than 1 mycotoxin.

Advantages of rapid testing

Nora Kogelnik, Romer Labs product manager, talked about the main advantages of mycotoxin rapid tests, highlighting:

- Fast and Precise Results
- No laboratory experience needed
- Test and results can be carried out on-site
- Minimising/preventing disposal of organic solvents

However, while rapid testing is great for raw grains and nuts and grain by-products, Kogelnik admitted it was more limited for finished feed or silage samples. Finished feed is often a complex matrix with formulations which can vary widely.

For example, feed formulations can be split into 3:

- **Protein meal** – vegetable proteins, soybean, canola, animal proteins, meat, bone or fish
- **Grains** – wheat, corn, barley, sorghum or rye
- **Vitamins, Minerals and Fats** – fats and oils, vitamins, minerals, amino acids.

Multi-mycotoxin analysis

Mueller touch on multi-mycotoxin analysis and highlighted 3 which could cause issues for livestock producers:

Beauvericin and Enniatin: These have effects on immune systems and accumulate in fat-rich tissue. Enn B, B1+Beauvericin showed effect on microbiome of piglets and caused histological lesions in piglet's liver.

Moniliformin: Broilers can be very susceptible as this mycotoxin can cause heart damage, muscular weakness, respiratory distress and immuno-suppression issues.

Alternariol: No acute toxicity; cytotoxic and mutagenic in vitro, effects on reproductive and immune system in vitro

She also spoke about some analysis carried out on peas, lupins, beans and chickpeas, saying that although sample levels (60) were low, she had been surprised by the number of contaminations (FUM 28%), being the highest and the range of metabolites.

And she urged the sector to look at the 3 areas of solutions to reduce mycotoxins – adsorption (synergistic blend of minerals), biotransformation and bio protection products.

► **What are emerging sensor technologies for Agriculture 4.0?**

Jul 2022 | https://www.sensortips.com/featured/what-are-emerging-sensor-technologies-for-agriculture-4-0-faq/

Agriculture 4.0 is emerging and requires an expended sensor suite. Agriculture 4.0 refers to systems that employ drones, robotics, the Internet of Things (IoT), vertical farms, artificial intelligence (AI), renewable energy, and advanced sensor methodologies. Agriculture 4.0 is similar to Industry 4.0 in some ways: Where Industry 4.0 is designed to support automation and mass customization of production processes, Agriculture 4.0 is expected to support autonomous operations and mass customization of farming practices across microenvironments.

Integrating digital technologies into farming, agricultural operations can target resources needed to increase yields, reduce costs, and minimize crop damage, water, fuel, and fertilizer usage. This FAQ looks at sensor technologies under development for Agriculture 4.0, including wearables for plants and hyperspectral imaging, the EU's Agricultural Interoperability and Analysis System program, and the security challenges related to wireless sensor networks and the Internet of Things in Agriculture 4.0.

Wearables for plants

Graphene and fiber optics are two technologies used to develop wearable sensors for plants. Graphene sensors can measure the time it takes for different crops to move water from the roots to the lower and upper leaves. Initially, researchers are using these sensors to help develop plants that use water more efficiently. In the longer term, these graphene sensors on tape (also referred to as 'plant tattoos') are expected to support the design of inexpensive, high-performance sensors for Agriculture 4.0 applications (Figure 1) and help improve the efficiency of irrigation systems. The process used to make the sensors can produce devices that are several millimeters across with features as small as 5 µm. The small feature sizes increase the sensitivity of the sensors. The conductivity of the graphene oxide in these sensors changes in the presence of water vapor, enabling the measurement of transpiration (the release of water vapor) from a leaf.

Fiber Bragg grating (FBG) sensing technology is also being developed for agricultural applications. An FBG acts as a notch filter that reflects a narrow portion of light centered around the Bragg wavelength (λ_B) when illuminated by a broad light spectrum. It's fabricated as a microstructure inscribed into the core of an optical fiber. Unlike graphene sensors, which are an emerging technology, FBG sensors are already in use in several areas, including aerospace, civil engineering, and human health monitoring. FBG sensors can be fabricated with high sensitivities, small size, and lightweight. In the case of agricultural sensors, the intrinsic sensitivity to strain (ε), and temperature variations (ΔT) of FBG technology are being combined with a moisture-activated polymer to detect relative humidity changes (ΔRH) in the surrounding air. In addition, FBG sensors can be multiplexed to support monitoring of both plant growth and environmental conditions in a single device. The FBG designed for agricultural applications consists of three segments, one for ε sensing, one for ΔRH monitoring, and a third optimized for ΔT measurements. It was fabricated using a commercial FBG with a grating length of 10 mm, λ_B of 1533 nm with a stretchable acrylate coating. The coating protects the FBG and improves its adherence to the plant's stem.

From multispectral to hyperspectral imaging

Multispectral imaging is an established agricultural sensing technology. It can detect subtle changes in plant health before visible symptoms are apparent. For example, a drop in a plant's chlorophyll content can be detected before the leaves are visibly yellow. Multispectral sensors use the 712 to 722 nm wavelengths (the red edge band) where indications of stress are most easily identified. Multispectral imaging can be implemented using fixed installations where the sensors travel back and forth on a track system in a greenhouse or across an open field. They are also well suited to be carried aloft on a drone. For example, in one configuration, a drone-based multispectral imaging system can scan a 100-acre field (at 400 feet above the found with a 70% overlap) in less than 30 minutes **(Figure 2)**. Some of the benefits of multispectral imaging include:

Early disease detection

Improved irrigation and water management

Quicker and more accurate plant counting to optimize fertilizer application and pest control

Cost reductions from the automation of activities previously performed by walking the fields

The primary difference between today's multispectral sensors and emerging hyperspectral sensors is the bandwidth (the number of bands and how narrow the bands are) used to represent the data of the electromagnetic spectrum. Multispectral imagery generally uses 3 to 10 bands to cover the relevant spectrum. Hyperspectral imagery consists of hundreds or thousands of narrower bands (10 to 20 nm), providing greater resolution, and covering a broader spectrum range. Spectral resolution, the ability to capture a large number of narrow spectral bands, is an important feature of hyperspectral imaging compared with multispectral imaging. Other advantages of hyperspectral imaging include:

Higher spatial resolution and the ability to discriminate smaller features,

Higher temporal resolution and the ability to more quickly sense important environmental changes such as the need for irrigation

Higher radiometric sensitivity and the ability to discern small differences in radiated energy

Hyperspectral imaging sensors provide a highly detailed electromagnetic spectrum of agricultural fields, making it a useful tool for detecting smaller and more localized variations in important soil attributes and degradation, as well as changes in crop health and fitness. The increasing use of sensors in Agriculture 4.0 and the addition of higher resolution sensors such as hyperspectral imaging is driving the use of big data and raising concerns related to data security, data integrity, and privacy. Addressing those concerns is a major emphasis for the EU's ATLAS program.

Agricultural interoperability and analysis system

The EU-funded Agricultural Interoperability and Analysis System (ATLAS) project aims to develop an open platform to support innovation and Agriculture 4.0. ATLAS is one of the EU's Horizon 2020 research and innovation programs. The Fraunhofer Society is managing the project. It addresses the current lack of data interoperability in agriculture by combining agricultural equipment with sensor systems and data analysis. The resulting platform is expected to support the integration of hardware and software interoperability from a wide variety of sensor systems and amplify the benefits of digital agriculture. ATLAS aims to develop an open interoperability network for agricultural applications and build a sustainable ecosystem for innovative data-driven agriculture (Figure 3). ATLAS is building on networks of in-the-field sensors and multi-sensor systems to provide the big data needed to realize Agriculture 4.0.

The ATLAS platform is expected to support the flexible combination of agricultural machinery, sensor systems, and data analysis tools to overcome the current lack of interoperability and enable farmers to increase their productivity sustainably by using the most advanced digital technology and data. ATLAS will also define layers of hardware and software to allow the acquisition and sharing of data from a multitude of sensors and the analysis of this data using a variety of dedicated analysis approaches. The program will demonstrate the benefits of Agriculture 4.0 through a series of pilot studies across the agricultural value chain and end by defining the next generation of standards needed to continue the growing adoption of data-driven architecture.

Wireless sensor networks and security

Wireless Sensor Networks (WSNs) and Internet of Things (IoT) solutions are extensively used in Agriculture 4.0, providing numerous benefits to the farmers. However, the interconnection among diverse sensors and network devices, which can contain unpatched or outdated firmware or software, creates opportunities for network insecurities and opens various attack vectors, including device attacks, data attacks, privacy attacks, network attacks, and so on.

The increasing use of automation and even autonomous operations to improve yields also raises safety concerns. In addition to ATLAS, the European Union's Horizon 2020 research and innovation programs focus on developing network traffic monitoring and classification tools for use in Agriculture 4.0 systems. Effective traffic monitoring is expected to play an essential role in protecting assistants and users from the impacts of network attacks. Network traffic analysis and classification tools are being developed for Agriculture 4.0 based on Machine Learning (ML) methodologies to help mitigate the threats to WSNs and other IoT-connected assets.

Summary

The deployment of Agriculture 4.0 relies on the increasing use of WSNs to improve yields and reduce costs for farmers. It also requires the development of new sensor modalities, such as plant wearables using

graphene-based and FBG sensors, and the expansion of existing sensor modalities, such as the move from multispectral to hyperspectral imaging. The EU's ATLAS program is designed to improve interoperability and realize the maximum benefit from the growing diversity of sensor and data analysis technologies. Improvements in network security will also be essential to ensure data security, integrity, and privacy in Agriculture 4.0.

► **The Biggest Future Trends In Agriculture And Food Production**

Jan 2022 | https://www.forbes.com/sites/bernardmarr/2022/01/28/the-biggest-future-trends-in-agriculture-and-food-production/?sh=6ed4575107a2

To feed the growing global population, estimates suggest we'll have to increase food production by as much as 68 percent by 2050. And that's not the only challenge; there's also the fact that the middle-class population is growing, which generally brings with it increased demand for meat over grains, legumes, and wheat. Satisfying this demand for more food – and, most likely, more meat – presents a huge challenge for our already struggling planet, especially when you consider that the food system accounts for 26 percent of total global greenhouse gas emissions. (Agriculture, forestry, and land use make up 18.4 percent of this, while the rest is down to things like packaging, refrigeration, and transport.)

The Biggest Future Trends In Agriculture And Food Production

The obvious, and arguably the simplest, solution is for us all to adopt a plant-based diet. (Research shows that excluding meat and dairy is the single most impactful way for people to reduce their environmental impact.) But, if we're honest, getting billions of people to switch overnight to a fully vegan diet is, at best, unlikely. After all, meat is deeply ingrained in many cultures, as is dairy.

With all this in mind, it's clear that we need urgent new innovations in agriculture and food production. In this article, I outline the two broad trends that I believe will revolutionize our food system.

Trend 1: Reimagining farming methods

Embracing new farming methods could help the agriculture industry reduce its environmental impact while still increasing productivity. While previous evolutions in farming have largely been driven by mechanical improvements (namely, bigger, better machinery) or genetic advances (better seed, more effective fertilizers, etc.), the next big transformation is being driven by digital tools. For example, we have:

- Automation – including the use of robots, drones, and autonomous tractors to make farming more efficient.
- Precision farming – which involves applying irrigation, fertilizers, and pesticides at variable rates, depending on the needs of crops, rather than uniformly applying them at set times, quantities, and frequencies.

A good example of precision farming comes from a collaboration between Israeli company Phytech and Swiss agrichemical company Syngenta. Together, they have developed a monitoring system that includes plant growth sensors and soil moisture sensors to help farmers continually monitor crop growth and soil health and take action when and where it's needed.

Other key trends to watch in farming methods include:

- More localized, urban farming – i.e., producing food closer to the people who need it, thereby reducing food miles.
- Vertical farming (the practice of growing crops in vertical layers) and hydroponics (growing plants in nutrient-rich water) – are both methods that generally use less water, soil, and space than traditional field farming methods. If this sounds niche, think again; the world's largest vertical farm, located in Newark, New Jersey, shows that vertical farming can be done on a huge scale and with

impressive results. Creators AeroFarm say the vertical farm is 390 times more productive per square foot than a field farm.

Trend 2: Finding new ways to create food (especially meat)

Did you know that one-third of croplands are used to grow feed for livestock rather than humans? It's an astonishing statistic. If we could only find innovative new ways to create meat, more of that land could be given over to growing crops for humans – something that will surely become more pressing as the global population grows.

This is where cultured (lab-grown) and plant-based meats come into play. Starting with plant-based meats, it's clear that the market for meat alternatives is thriving. Chains like Burger King are routinely stocking plant-based burgers, and plant-based pioneers Beyond Meat became one of the most successful IPOs in history after going public at $1.5 billion and being valued at $13 billion less than three months later. In fact, estimates suggest meat alternatives could account for 10 percent of the global meat industry by 2029.

For those who don't want to make the switch to plant-based meats, cultured meat – which is genetically the same as real meat but is produced from animal cells – could prove to be a viable alternative. Real meat without the factory farms and animal slaughter? Sounds pretty good to me. It's early days for cultured meat, but there are signs that the market – and regulators – are coming around to the idea. In 2020, Singapore became the first nation to approve cultured meat for sale.

There's also the potential for 3D printing to play a role in food production. Barcelona-based startup NovaMeat is leading the way in 3D printing plant-based food and has already successfully created the world's first 3D printed piece of "meat" that apparently mimics the fibrous nature of real meat.

- **THE NEXT BIG THING IN AGRICULTURE: HOW SMART SENSORS HELP FARMERS GROW BETTER CROPS**

Dec 2021 | https://growtunnels.com/blogs/news/the-next-big-thing-in-agriculture-how-smart-sensors-help-farmers-grow-better-crops

Smart agriculture sensors are the new frontier in farming. With the help of sensors, farmers are able to maximise efficiency in their fields and ensure that they use only the necessary amount of fertiliser, water and protectants.

In recent years, the agricultural industry has become more reliant on technology to achieve better yields and higher quality produce. This article provides a great summary on how smart sensors can help agriculture.

Using smart sensors, farmers can also quickly diagnose problems in their crops and take action before it's too late. Smart sensors can even be used to monitor soil conditions, pest levels and other parameters that affect their health.

WHAT ARE AGRICULTURAL SMART SENSORS?

Smart sensors are digital devices placed in the soil to monitor air temperature, soil temperature, air humidity and soil moisture levels. Real-time readings are sent via a wifi connection, to a centralised database, providing high-detail data and precise knowledge of growing conditions to growers, allowing them to monitor crop conditions, respond accordingly and improve their yield capabilities.

HOW DOES A SMART SENSOR WORK?

A smart sensor device takes readings on the physical environment around it, in order to provide details of specific inputs, feeding this information to user websites and mobile apps via a centralised database.

Agricultural smart sensor products are part of the 'Internet of Things' (IoT), providing seamless communication between the digital farm sensor and the farmer, monitoring and reporting on environmental conditions in real-time.

SmartFarm Sensors can be placed in the soil and measure soil moisture at four depths - recording readings periodically. This data can be accessed via mobile devices, tablets or computers and analysed for patterns, sending alerts and notifications to growers in real-time.

HOW CAN SMART SENSORS IMPROVE YOUR FARM?

When it comes to the agricultural industry, smart sensors can assist farmers and growers to make the best decisions regarding the growing conditions for their crops. At the touch of a button, they are able to determine whether soil conditions need improving, manage irrigation requirements and monitor disease pressures, based upon real-time data.

SmartFarm Sensors are a compact and affordable way to provide the data, along with the digital platform to monitor and record the data, on four key growing conditions; air temperature, air humidity, soil temperature and soil moisture. The precise measurements provided by the device can help save farmers money, by minimising costly inputs - such as water and fertilisers. It can also help maximise yields, by ensuring that crops are growing in an optimum environment. Here's how each of these measurements helps your bottom-line:

AIR TEMPERATURE:

Every plant will have an optimal temperature for plant growth, flowering and fruiting as well as the rate at which photosynthesis occurs. Photosynthesis increases as temperatures rise and transportation of sugars occurs mostly during the night, or coolest parts of the day. Being able to monitor the air temperature, allows growers to respond and alter growing conditions, to provide the crop with the optimal air temperature – particularly when growing in an enclosed environment such as our GROWTunnels.

AIR HUMIDITY:

Humidity has a significant effect on plant growth, especially during germination and flowering. Measuring air humidity with smart sensors, allows growers to ensure there are suitable levels of water vapor present in the air.

High humidity makes it difficult for plants to absorb water from the soil and can cause disease. It also affects soil aeration and the ability of roots to absorb oxygen from the soil.

Low humidity causes leaves to dry out and lose turgor pressure, reducing their ability to take in carbon dioxide through their stomata. If the air is too dry then the plant will have a hard time absorbing enough water, causing the leaves to wilt and drop which reduces crop yields. It also causes less fruit to form on plants, resulting in less product being produced. If a crop is already stressed out from too much heat or cold, then low humidity will make it even more stressed.

SOIL TEMPERATURE:

The soil temperature is important for crop production. It directly affects the growth of plants, influences the rate of germination of seeds and of course, the crops final yield. Soil microbes, which are critical to crop production are also affected by soil temperature. Therefore, monitoring the temperature of soil, using an agricultural smart sensor is also a good way to ensure optimal environmental conditions and management practices.

Temperature has a direct effect on many biological processes in plants. The reaction time of the metabolic processes is shorter at higher temperatures. In addition to absorption, the rate of many chemical reactions increases with increasing temperature. The amount of water lost through evaporation from the leaves will

increase with increasing temperature, if there is no change in relative humidity. Furthermore, plants have different optimal temperatures for each stage in their life cycle.

Temperature affects both the quantity and quality of crops grown. For example, a soil temperature above 30 degrees Celsius has been shown to decrease yield by around 25%. Cool soils that are wet to moist will produce higher yields than hot and dry soils.

SOIL MOISTURE:

The importance of soil moisture monitoring cannot be overstated when it comes to improving crop yield, as it gives an indication of the water stored in the soil, which is necessary for the growth of plants.

Surface soil moisture is a significant factor influencing the yields of various crops. It is well documented that plants must be supplied with adequate moisture at all stages of their growth to achieve maximum yields. But it's not just about what's on the surface that counts.

SmartFarm Sensors are placed in the soil and measure soil moisture at four depths, providing useful information on water movement through the soil, and therefore can also indicate soil consistency.

A study in China showed that corn yields increased by 10% when the soil moisture content was maintained above 50%. The study was done on a large scale at three locations in different soil types, which revealed similar results. However, cropping time and planting depth are also important for increasing soil moisture as well as crop yield. Whilst another study across four states in India showed that wheat production decreased by 30% when the soil moisture content was below 30%. It is therefore evident that monitoring soil moisture and adjusting irrigation requirements accordingly, is an effective way for farmers to increase their crop yields and overall plant health.

FUTURE OF AGRICULTURE AND SMART SENSORS:

Smart sensors have already been proven a very useful tool, for both small-scale operations and use in predicting large agricultural events such as drought.

In California, soil moisture sensors were able to detect the dryness of the soil and send out alerts before the drought became too big to handle.Here in Australia, the Department of Agriculture and Water Resources estimate that using smart farming sensors could potentially increase Agricultural contributions to GDP by US$15.8 billion. The University of Adelaide is currently conducting research utilising smart sensors in viticulture, in order to enable better prediction of vineyard outcomes, including fruit yield and quality. Research such as this will provide crucial decision-making information to help improve farm yields and benefits growers annual returns.

As the use of smart technology grows in the agricultural industry, we hope to see that smart sensors could potentially link into other smart farming systems, controlling irrigation inputs, identifying crop pattern recognition and even executing weed control.

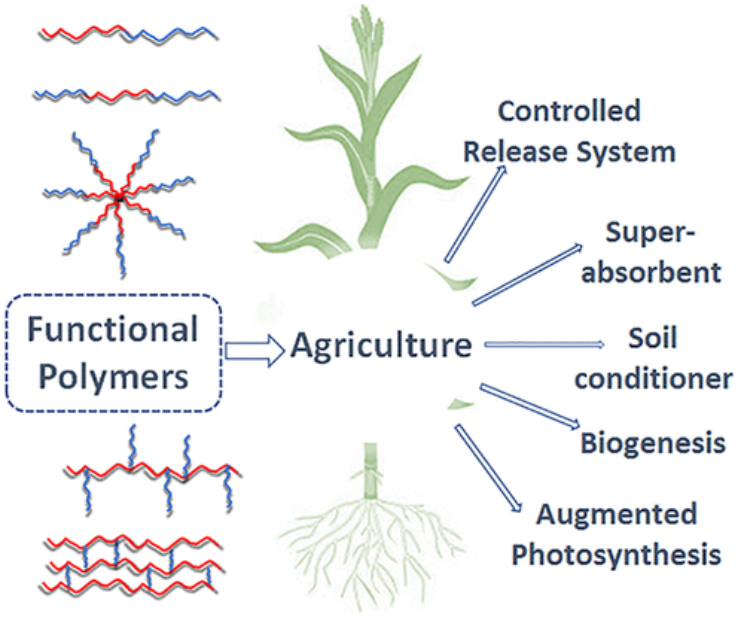
When it comes to improving your farm, you can't afford to not have all the right information at your fingertips. Thanks to the rapidly changing world of agribusiness and new technological advancements, farmers can be more effective and efficient in their work.

SmartFarm sensors allow you to monitor and improve your farming operations, based on reliable data that will help you make better decisions on the fly.

Structural Materials

- **Recent Trends in Advanced Polymer Materials in Agriculture Related Applications**

Feb 2021 | https://pubs.acs.org/doi/10.1021/acsapm.0c00982



Over the past few decades, advanced polymeric materials have gained popularity in the development of sustainable agricultural applications. Smart polymeric systems have extensively contributed to the agricultural industry by increasing the efficiency of pesticides, herbicides, and fertilizers by facilitating controlled release systems and, therefore, enabling lower doses to be used. Superabsorbent polymeric materials have been used as soil conditioners to control the impact of drought, whereas polycationic polymers have been utilized for plant bioengineering. These functions in the environment are complemented by applications within plants as part of the developing range of tools for genetically transforming plants in order to increase productivity and disease resistance. This Review will summarize and discuss the recent developments in the design and application of advanced polymeric systems for precision agriculture related applications. The design criteria of the polymers employed to date, such as polymer structure, as well as the properties of polymer nanoparticles including shape and size will be discussed, and the key findings in the related area will be highlighted. Finally, we will identify future directions for the exploration of functional polymers with the ultimate aim of advancing sustainable agriculture.

- **Canada Construction Market Size, Trend, Analysis by Sector and Forecast, 2023-2027**

Jun 2023 | https://www.globaldata.com/store/report/canada-construction-market-analysis/

The Canada construction market size was $355.9 billion in 2022. The market is projected to achieve an AAGR of more than 1% during 2024-2027. The construction industry output in the forecast period will be supported by developments in the industrial, energy, and transportation sectors.

The key sectors in the Canada construction market are commercial construction, industrial construction, infrastructure construction, energy and utilities construction, institutional construction, and residential construction. Residential construction was the leading sector in the Canada construction market in 2022.

- **Commercial construction**: Due to rising inflation, a shortage of skilled labor, and high borrowing costs, the commercial construction sector is expected to remain fairly sluggish in the early part of the forecast period. However, the sector will be supported by the government's goal of generating revenue in the tourism sector by 2030.
- **Industrial construction**: Output in the industrial sector will be supported by investment in Electric Vehicle (EV) markets and the government's goal of transforming the country into an industrial hub.
- **Infrastructure construction**: The growth of the infrastructure construction sector will be driven by investments by both the federal and regional governments in the development of the country's transportation network.
- **Energy and utilities construction**: Forecast-period growth in the energy and utilities sector will be aided by developments in the oil and gas markets, in line with the government's estimate of generating over $495 billion in oil and gas revenues from 2023 to 2032.
- **Institutional construction**: A rising healthcare demand will drive public and private investment in the institutional sector over the forecast period.
- **Residential construction**: The residential construction sector is expected to remain weak in the short term, as recent interest rate hikes and high construction costs have impacted on demand. In the long term, the government's emphasis on affordable housing construction, combined with investments from the federal and regional governments, will ensure the sector's output picks up.

The leading contractors in the Canada construction market are SNC-Lavalin Group Inc, Fluor Corp, Kiewit Corp, Aecon Group Inc, PCL Constructors Inc, Vinci SA, EllisDon Corporation, Actividades de Construccion y Servicios SA, Graham Group Ltd, and Bird Construction Inc, among others. SNC-Lavalin Group Inc led the market.

Intellectual Property Research Results

Using semantic searches in PatSnap, patent databases were surveyed to identify technologies that are similar in form or function to the subject invention. Such technologies provide a picture of the competitive state of the marketplace and the patent landscape. At the same time, companies that are active in the field may be prospective partners/licensees. The following figures provide a graphical representation of the search results.

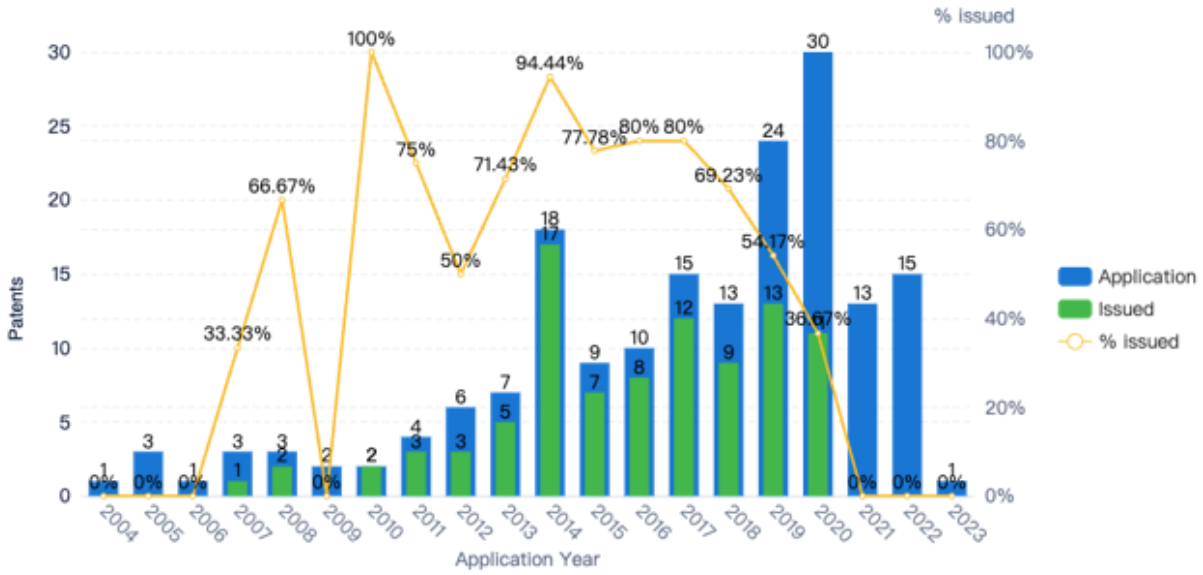
As patents do not publish for 12 months, most recent year data will be lagging (show fewer results) and should not be construed as a declining trend.

NOTE: This search was not intended to be comprehensive, and although potentially relevant patents have been identified, no attempt was made to fully determine the patentability or freedom to operate for the subject invention. Nor was an attempt made to determine whether the practice of another patent might infringe upon patents for the subject technology. The client is urged to consult a patent attorney regarding any such questions or concerns.

Sensors

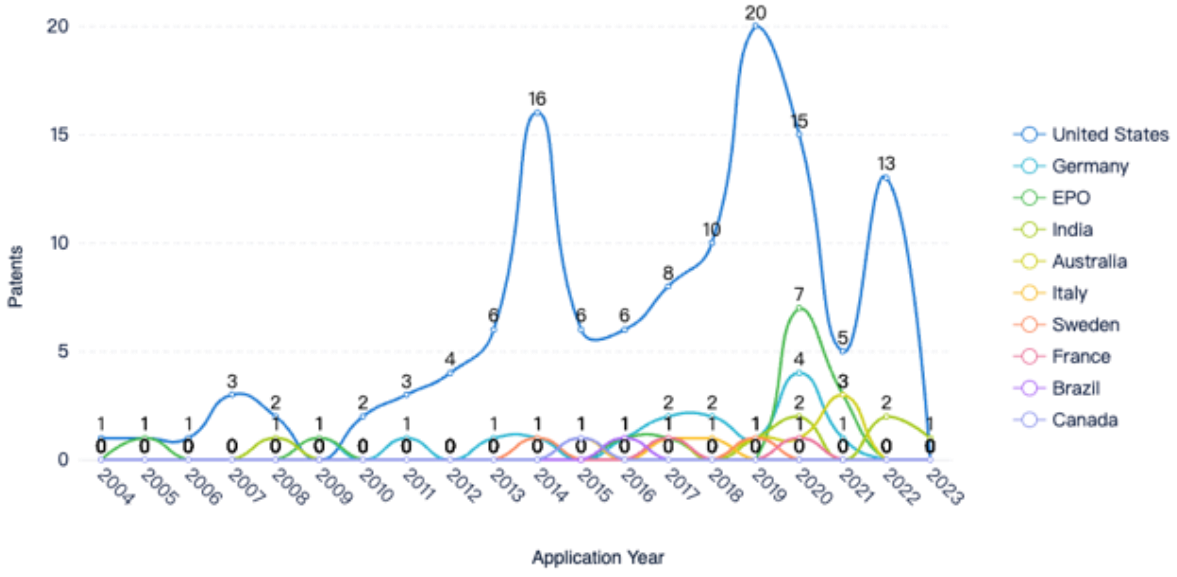
IP FIGURE 1 INNOVATION RATE

The graph below shows the yearly patent application trend. This trend approximates the innovation rate in the technology field.



IP FIGURE 2 APPLICATION TREND IN TOP COUNTRIES

The yearly trend of patent applications by geography provides an indicator of the geographic markets for the technology field. The countries/regions with the most application activity are shown. This information can be used to inform and prioritize potential foreign filings as well as to identify countries in which to seek licensees.



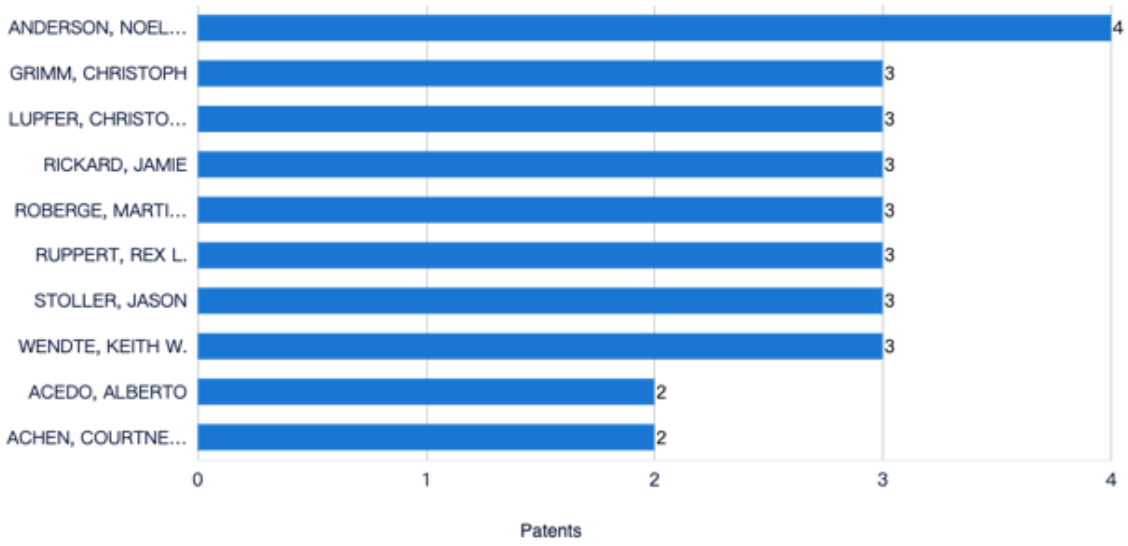
IP FIGURE 3 ASSIGNEE PATENTING ACTIVITY BY TECHNOLOGY AREA

The technology field lattice map plots the top company assignees within a technology field clustered into the various technology keyword/phrases from the patent documents. Each cell (lattice) represents the same number of patents. This can be used to identify potential licensees/partners and their areas of interest.



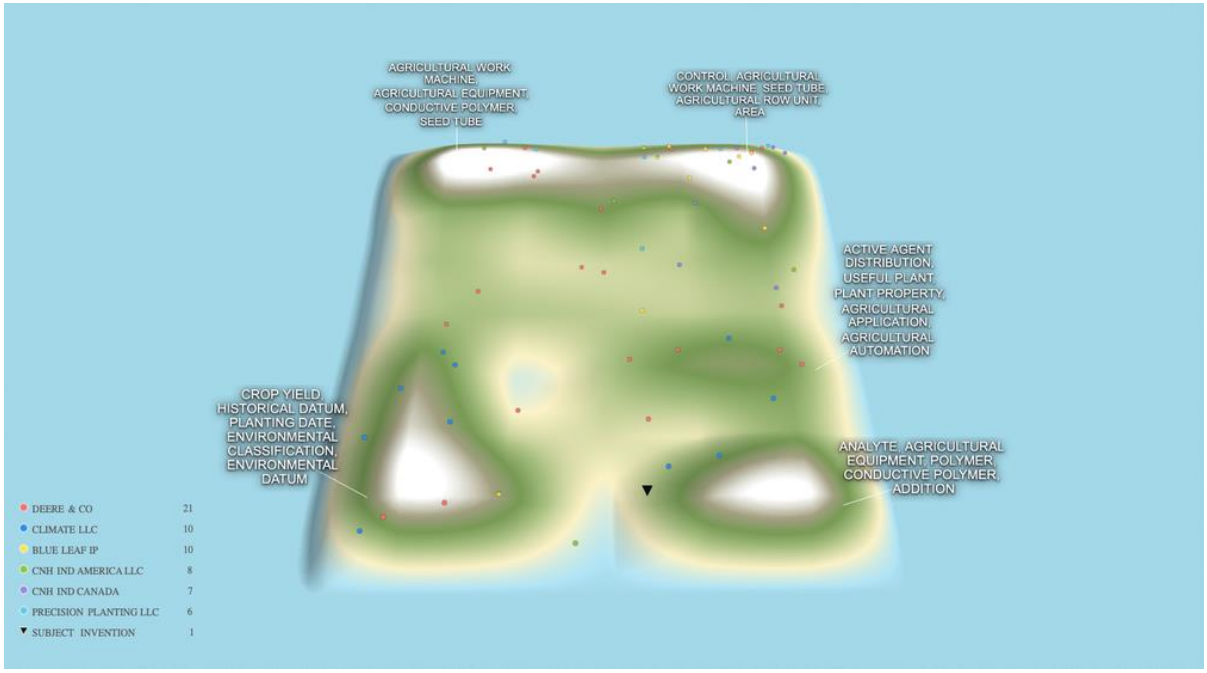
IP FIGURE 4 TOP INVENTORS

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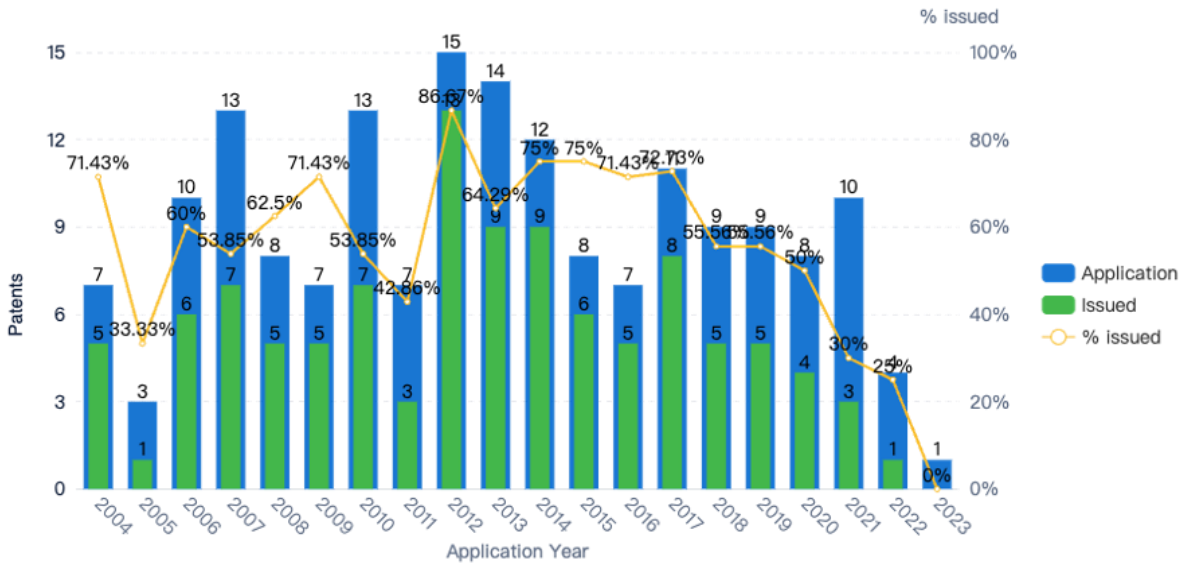
IP FIGURE 5 LANDSCAPE MAP

Peaks in the landscape indicate densely populated areas of patent development. The triangle shows where the subject technology fits in the landscape. Key player patents may also by highlighted in the figure.



Electric Technology

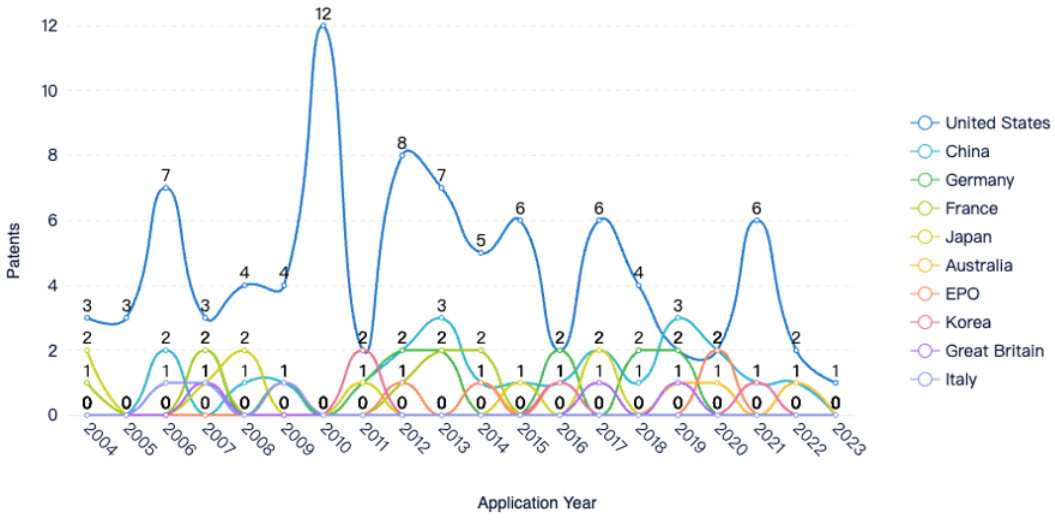
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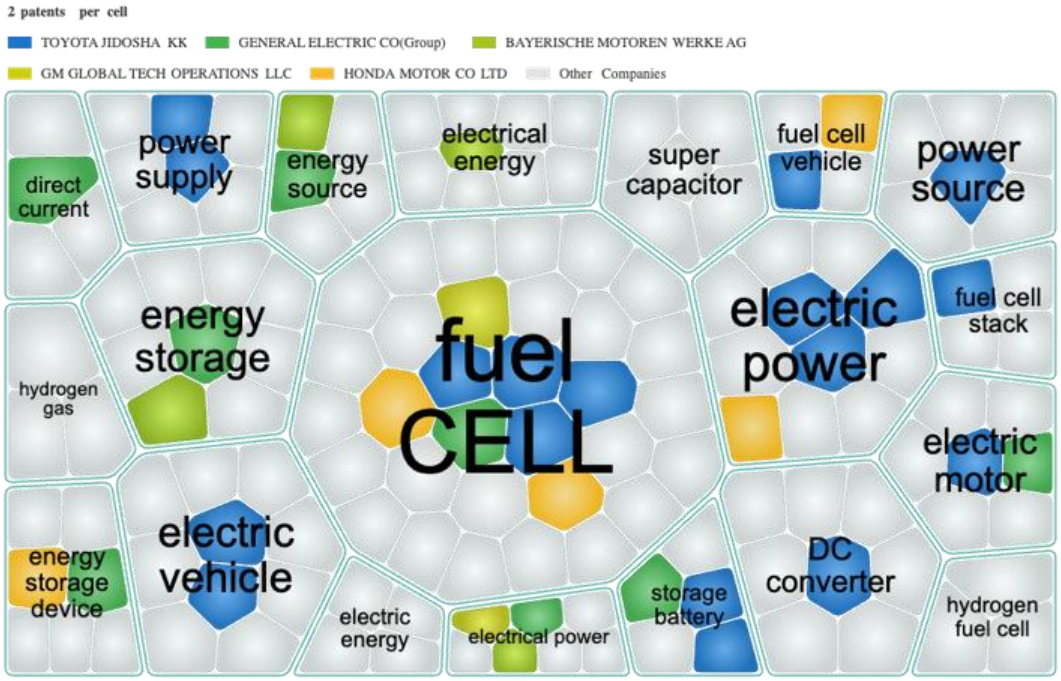
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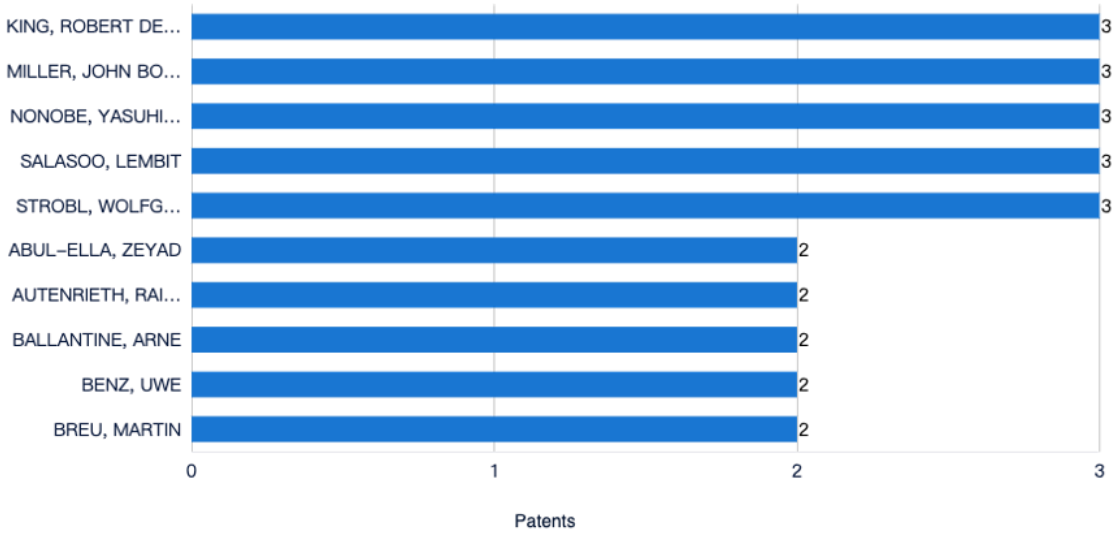
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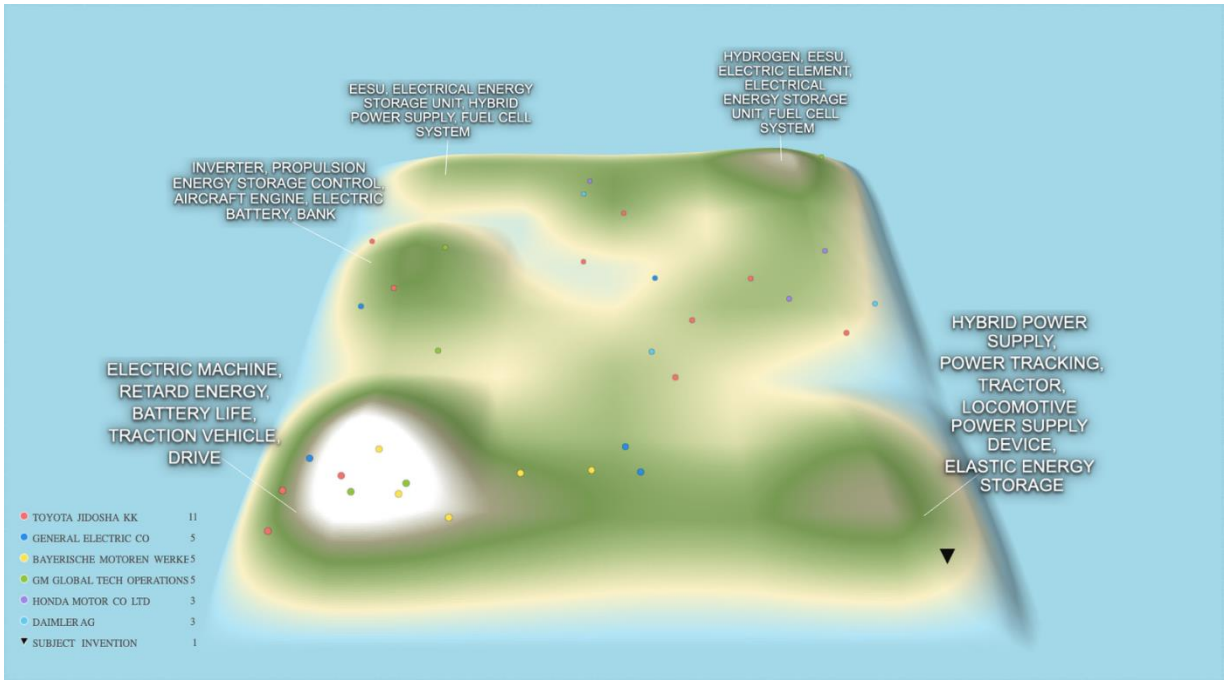
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Closely Related Patents

The following patents were identified as potentially closely related to this technology. Only titles and abstracts were reviewed for relevance, and they should be further reviewed to confirm how they may impact the subject technology for novelty and arguably non-obvious aspects in comparison. The information includes:

- Publication Number (linked to the document)
- Title
- Application Date
- Publication Date
- Assignee
- Abstract

Electrification of Agricultural Equipment

Publication Number	Title	Application Date	Publication Date	Assignee(s)
US7028792B2	Electric vehicle and performance setting method	2004-02-11	2006-04-18	TOYOTA JIDOSHA KABUSHIKI KAISHA
US10486543B2	Voltage control device for fuel-cell vehicle	2017-10-24	2019-11-26	TOYOTA JIDOSHA KABUSHIKI KAISHA
US10358050B2	Fuel cell vehicle and method for controlling fuel cell vehicle	2017-10-30	2019-07-23	KABUSHIKI KAISHA TOYOTA JIDOSHOKKI | TOYOTA JIDOSHA KABUSHIKI KAISHA
US20080257621A1	Fuel cell vehicle system	2008-04-09	2008-10-23	HONDA MOTOR CO., LTD.
GB2587666A8	Hybrid hydrogen power module	2019-10-04	2022-02-23	ANGLO AMERICAN TECHNICAL & SUSTAINABILITY SERVICES LTD
US20220203844A1	Power generation systems and methods for controlling cascaded batteries and fuel cells with supercapacitors	2021-12-29	2022-06-30	CUMMINS INC.
US20220340048A1	Dual battery fuel cell system	2021-04-14	2022-10-27	TOYOTA MOTOR ENGINEERING & MANUFACTURING NORTH AMERICA, INC.
CN109398112A	Fuel cell and super capacitor hybrid driven tractor and application thereof	2018-10-18	2019-03-01	FENGJIANG INTELLIGENT TECHNOLOGY CO., LTD.

Publication Number	Title	Application Date	Publication Date	Assignee(s)
WO2021046604A1	Managing capacitive charge storage or delivery for a hybrid power system	2020-09-09	2021-03-18	AIQ HYBRID PTY LTD
CN102343826A	New energy electric automobile	2011-07-18	2012-02-08	CHEN CHANGZHI
WO2019153050A1	Hybrid powertrains	2019-02-08	2019-08-15	AIQ HYBRID PTY LTD
US20080087479A1	Power system of hybrid fuel cell bus and control method thereof	2007-01-04	2008-04-17	HYUNDAI MOTOR COMPANY
US20070138006A1	System and Method for Generating Hydrogen Gas	2006-12-19	2007-06-21	CENESTRA LLC
WO2023129616A1	Supercapacitor to electrochemical hybrid system with a supercapacitor battery management capability	2022-12-28	2023-07-06	SUSTAINABLE ENERGY TECHNOLOGIES, INC.
CN201128382Y	Super-capacitor energy-saving port tractor	2008-02-27	2008-10-08	JIANGSU JINCHI VEHICLE CO., LTD.
WO2014044340A3	Method for operating a fuel cell system	2013-08-16	2014-06-19	DAIMLER AG
US20150073632A1	Tri-hybrid automotive power plant	2014-03-11	2015-03-12	HILL, NICHOLAS
US20030132097A1	Fuel-cell powered desalination device	2002-01-15	2003-07-17	KENET, BRIAN | BELMAR, PEDRO JOAQUIN SANCHEZ
EP3210816A1	Fuel cell hybrid power system	2016-02-23	2017-08-30	UNIVERSITY OF HERTFORDSHIRE HIGHER EDUCATION CORPORATION

Sensors

Publication Number	Title	Application Date	Publication Date	Assignee(s)
US10502606B2	Wireless particulate solid material flow sensor with internal battery	2016-10-05	2019-12-10	DO AMARAL ASSY, JOSE ROBERTO
EP3729943B1	Agricultural machine and method performed by said agricultural machine	2020-04-22	2022-03-23	DEERE & COMPANY
US11035838B2	Automated soil sensor system adaptable to agricultural equipment, trucks, or all terrain vehicles	2018-04-09	2021-06-15	CROPTIMISTIC TECHNOLOGY INC.
US10820505B2	Self-learning grain sensing system	2018-09-11	2020-11-03	DEERE & COMPANY
US10989833B2	Systems and methods for monitoring grain loss	2019-09-24	2021-04-27	DEERE & COMPANY
EP4039074A1	Method of controlling an agricultural work machine	2022-01-26	2022-08-10	DEERE & COMPANY
EP3453004B1	Self-standing mobile detection device, related system and process for the detection and the monitoring of chemical-physical parameters inside a container for the storage and/or the transportation of solid material	2018-03-16	2021-12-08	OPEN FIELDS S.R.L.
AU2022200217A1	System and method for dispensing agricultural fluids onto plants present within a field based on plant size	2022-01-14	2022-08-04	CNH INDUSTRIAL AMERICA LLC
DE102020128075A1	method of applying sprays using an agricultural sprayer	2020-10-26	2022-04-28	Amazonen-Werke H. Dreyer SE & Co. KG
US5759286A	Method of recycling agricultural chemical rinse water into an irrigation system	1996-09-27	1998-06-02	SARVER, LARRY C.

Publication Number	Title	Application Date	Publication Date	Assignee(s)
WO2020034009A1	A computer-controlled agriculture system	2019-08-16	2020-02-20	MANSKI PTY LTD
WO2021032632A1	Apparatus and method for converting existing sowing equipment	2020-08-14	2021-02-25	SYNGENTA PARTICIPATIONS AG
BR112019013339A2	FERTILIZER SYSTEM FOR AGRICULTURAL SOILS, PROCESS FOR OPERATING A FERTILIZING SYSTEM	2017-12-19	2019-12-24	ROBERT BOSCH GMBH
US20140165854A1	Agricultural product containing and conditioning system	2012-08-08	2014-06-19	KONGSKILDE INDUSTRIES A/S
WO2023017328A1	Method and systems for using sensors to determine characteristics of seeds or particles	2022-06-16	2023-02-16	PRECISION PLANTING LLC
WO2012122050A2	Systems, devices, and methods for enviromental monitoring in agriculture	2012-03-02	2012-09-13	PURESENSE ENVIRONMENTAL INC. | FREY, MICHELLE, M.
WO2011069563A1	Method and system for monitoring and controlled distribution of fertilizers	2009-12-14	2011-06-16	UNITY AG | OTTO, ALBRECHT
US5737221A	Method for dispensing dry granular materials	1997-03-20	1998-04-07	AMVAC CHEMICAL CORPORATION
US6845326B1	Optical sensor for analyzing a stream of an agricultural product to determine its constituents	2000-11-07	2005-01-18	NDSU RESEARCH FOUNDATION
US6796504B2	System, apparatus and method for marking and tracking bulk flowable material	2000-12-15	2004-09-28	ROBINSON, MARTIN C.
US6591145B1	Systems and methods for autonomously controlling agricultural machinery	2000-09-21	2003-07-08	BATTELLE ENERGY ALLIANCE, LLC

Closely Related Publications

A search for potentially relevant non-patent literature was conducted using Google Scholar. The following articles were identified as relevant to this technology. These should be reviewed to confirm that the subject technology has novel and arguably non-obvious aspects in comparison.

Sustainable Agriculture

- **SUSTAINABLE AGRICULTURE**

No date | https://www.borregaard.com/markets/agriculture/sustainability/sustainable-agriculture/

Borregaard is the world's leading producer of sustainable lignin-based biopolymers, microfibrillar cellulose (MFC) and vanillin. Our environmentally friendly products can be used in a range of agricultural applications, including crop protection, plant nutrition, biocontrol and seed coating. They help farmers produce more food with less inputs.

Our lignosulfonates, Exilva® MFC products and wood-based EuroVanillin® Supreme are derived from **sustainably managed forests**. Most of our products are suitable for organic farming and represent **sustainable alternatives to synthetic polymers**.

- **Agricultural Waste Management: Problems and Treatments**

Apr 2022 | https://www.ijirmf.com/wp-content/uploads/IJIRMF202204025.pdf

4. AGRICULTURAL WASTE MANAGEMENT – TREATMENTS : How is agricultural waste disposed of? Methods of getting rid of agricultural waste:

Pyrolysis: Pyrolysis is one of the technologies available to convert biomass to an intermediate liquid product that can be refined to drop-in hydrocarbon biofuels, oxygenated fuel additives and petrochemical replacements. Pyrolysis is the heating of an organic material, such as biomass, in the absence of oxygen. Biomass pyrolysis is usually conducted at or above 500 °C, providing enough heat to deconstruct the strong bio-polymers mentioned above. Because no oxygen is present combustion does not occur, rather the biomass thermally decomposes into combustible gases and biochar. Pyrolysis is most commonly used in the treatment of organic materials Most of these combustible gases can be condensed into a combustible liquid, called pyrolysis oil (bio-oil), though there are some permanent gases (CO2, CO, H2, light hydrocarbons), some of which can be combusted to provide the heat for the process.

Landfills: A landfill is an engineered pit, in which layers of solid waste are filled, compacted and covered for final disposal. It is lined at the bottom to prevent groundwater pollution. Landfills need expert design as well as skilled operators and a proper management to guarantee their functionality. It is carefully designed structure built into or on top of the ground in which trash is isolated from the surrounding environment (groundwater, air, rain). This isolation is accomplished with a bottom liner and daily covering of soil. The purpose of a landfill is to bury he trash in such a way that it will be isolated from groundwater, will be kept dry and will not be in contact with air. Unlike a compost pile, a landfill is designed to keep the trash away from people, but does not allow it to decompose quickly.

Sanitary Landfills: A method of disposing of solid waste on land without creating hazards to public health or safety, by utilizing the principles of engineering to confine the solid waste to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at more frequent intervals as may be necessary.

Compost: Composting is a process by which organic wastes are broken down by microorganisms, generally bacteria and fungi, into simpler forms. The microorganisms use the carbon in the waste as an energy source.

The degradation of the nitrogen- containing materials results in the breakdown of the original materials into a much more uniform product which can be used as a soil amendment. Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. The compost made from farm waste like sugarcane trash, paddy straw, weeds and other plants and other waste is called farm compost.

Incineration : Incineration is a waste treatment process that involves the combustion of substances contained in waste materials. Industrial plants for waste incineration are commonly referred to as waste-to-energy facilities. Incineration and other high-temperature waste treatment systems are described as "thermal treatment". Incineration is a method of treating waste which involves the combustion of the organic substances found in waste materials. The solid mass of the original waste is reduced by around 80 to 85%, while the volume is reduced by between 95 and 96%. While incineration does not totally replace the process of landfilling, it does reduce the amount of waste to be disposed of considerably.

Cellulose & Fiber Extraction

- **Regenerated Cellulose Products for Agricultural and Their Potential: A Review**

Oct 2021 | https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8537589/

Abstract

Cellulose is one of the most abundant natural polymers with excellent biocompatibility, non-toxicity, flexibility, and renewable source. Regenerated cellulose (RC) products result from the dissolution-regeneration process risen from solvent and anti-solvent reagents, respectively. The regeneration process changes the cellulose chain conformation from cellulose I to cellulose II, leads the structure to have more amorphous regions with improved crystallinity, and inclines towards extensive modification on the RC products such as hydrogel, aerogel, cryogel, xerogel, fibers, membrane, and thin film. Recently, RC products are accentuated to be used in the agriculture field to develop future sustainable agriculture as alternatives to conventional agriculture systems. However, different solvent types and production techniques have great influences on the end properties of RC products. Besides, the fabrication of RC products from solely RC lacks excellent mechanical characteristics. Thus, the flexibility of RC has allowed it to be homogenously blended with other materials to enhance the final products' properties. This review will summarize the properties and preparation of potential RC-based products that reflect its application to replace soil the plantation medium, govern the release of the fertilizer, provide protection on crops and act as biosensors.

- **Cellulose-Based Hydrogels for Agricultures**

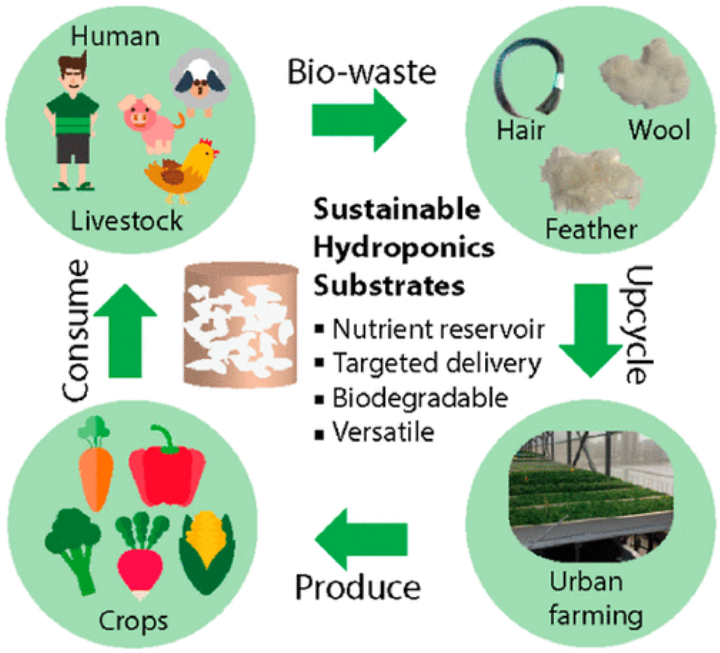
May 2018 | https://link.springer.com/referenceworkentry/10.1007/978-3-319-76573-0_34-1

The cellulose-based hydrogel characteristics such as biodegradability and biocompatibility mark its suitability toward agriculture application. In agriculture, the hydrogels are specifically used as water reservoirs, phyto-pharmaceuticals (protected cultivations, soilless cultivations, and open-field cultivations), pesticide release, and nutrient release to the soil. The hydrogels are impregnated by fertilizer components (e.g., soluble phosphate, potassium ions, nitrogen compounds), and those chemicals which are trapped in a polymer network cannot be immediately washed out by water but gradually released into the soil and then absorbed by plants. The hydrogels are classified as two classes, i.e., soluble and insoluble hydrogels. The soluble variety is used to reduce irrigation erosion in fields. The insoluble variety is used in gardens, nurseries, and landscapes to reduce frequency of watering. They are produced either in the form of powder or of a bulky material with a well-defined shape and a strong memory of its shape after swelling. The material can be charged with small molecules, such as nutrients, to be released under a controlled kinetic. The main advantage is controlled release of water, longtime maintaining soil humidity, increase of soil porosity, and therefore better oxygenation of plant roots. The agricultural hydrogel behavior depends on

various factors such as temperature, relative humidity, soil type, stress, etc. The performance of the gels is evaluated through different techniques like moisture retention, nutrition release rate, biodegradation rate, relative humidity, and temperature maintained in the soil. Several studies reveal that the amount of moisture retained in the soil is dependent on the concentration of the cellulose-based superabsorbent matrices. Those SAPs/hydrogels were used in specific agriculture application such as nutrient release, conservation of land, and drought stress reduction due to several advantages. The advantage of cellulose-based hydrogels include eco-friendliness, high water holding capacity, low cost, and biodegradability. Moreover, their application helps reduce irrigation water consumption, causes lower death rate of plants, improves fertilizer retention in soil, and increases plant growth rate.

- **Sustainable Nutrient Substrates for Enhanced Seedling Development in Hydroponics**

Jun 2022 | https://pubs.acs.org/doi/10.1021/acssuschemeng.2c01668



Sustainable agriculture can be achieved by upcycling and repurposing organic wastes for high-value applications. Keratin and cellulose are two natural biopolymers which are plentiful in biowastes such as hair, poultry feathers, wood shavings, and vegetable trimmings. In this study, these waste-derived biopolymers are converted into bioactive nutrient substrates that can support crop development in hydroponic culture systems. Keratin extracted from human hair (HHK) and cellulose nanofibers (CNFs) obtained from wood pulp were fabricated into composite substrates by freeze-drying. The substrates exhibited highly microporous structures, superior hydrophilicity, and excellent mechanical resilience. The obtained substrates not only serve as a physical carrier to support seed germination and seedling development but also function as advanced nutrient delivery platforms by the incorporation and controlled release of micronutrient-doped carbon dots, in addition to keratin degradation. Functional experiments using the model plant Arabidopsis and crops including Bok Choy (*Brassica rapa*) and Arugula (*Eruca vesicaria*) indicated that these substrates have the potential to be customized for enhanced seedling development in comparison to conventional substrates. This study demonstrates the feasibility and potential of upcycling and repurposing keratinous and cellulosic wastes to provide a sustainable solution for targeted nutrient delivery to crops.

► **Cellulose-Based Functional Materials for Sensing**

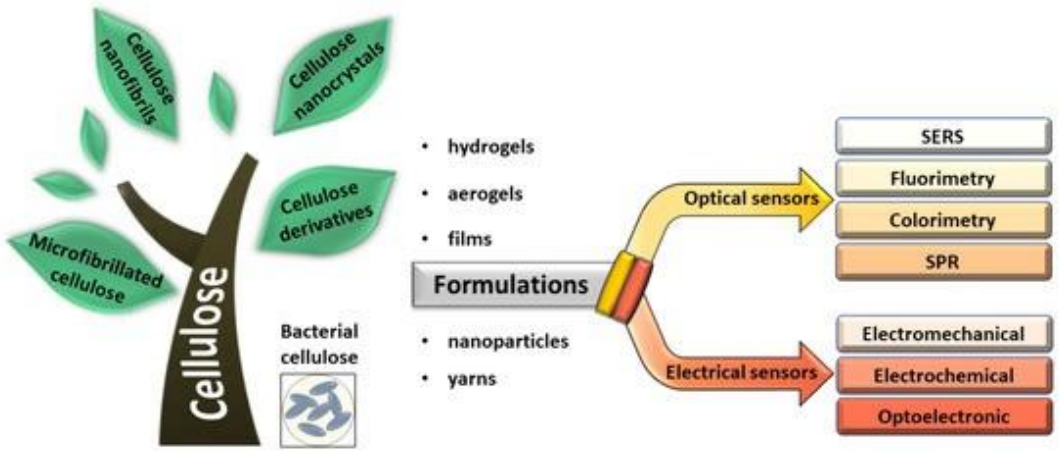
July 2022 | https://www.mdpi.com/2227-9040/10/9/352

Abstract

The growing bioeconomic demand for lightweight materials with combined sustainability, large-scale production, ease in functionalization and competitive mechanical properties has seen the revival of cellulose as a scaffold for several applications. In particular, due to its multifunctional features, cellulose has found application in sensor and biosensor fabrication. Nonetheless, the great variety of cellulose properties and formulations makes the choice of the best suited cellulose-based material for a specific sensing strategy a difficult task. This review offers a critical discussion and guide for the reader towards the understanding of which of the multiple cellulose derivatives and properties can be exploited for the optimal performance of the desired sensing device. We introduce the unique molecular structure, nanoarchitecture and main properties of cellulose and its derivatives. The different functionalization approaches for anchoring receptors on cellulose derivatives and the processing methodologies for fabricating cellulose-based sensors are explored. As far as the use and performance of cellulose-based functional materials in sensors is concerned, we discuss the recent advances of optical and electrochemical sensors and biosensors for biomedical and environmental monitoring.

Keywords:

cellulose derivatives; nanocelluloses; cellulose hydrogels; cellulose films; sustainable materials; biosensors; paper-based sensors; optical sensors; electrochemical sensors; immunoassays



5. Conclusions and Outlook

We have reviewed the fascinating properties of cellulose and cellulose derivatives, highlighting why this material is very suitable to develop sensors and biosensors for detecting varied analytes and physical changes. In particular, some of the cellulose features can be ascribed to (i) its molecular structure and nanostructure, (ii) its long-range structural organization (i.e., the chiral nematic phase which allows for optic detection of physical changes) and high processability, as for example the formation of 3D fibril networks, nanoparticles or films, (iii) its surface functionalization, which allows for both the covalent conjugation of receptors (antibodies, enzymes, etc.) or chromophores and the establishment of supramolecular interactions for the non-covalent association with nanomaterials (e.g., metallic nanoparticles, carbon-based nanomaterials, etc.) and (iv) its high specific-surface area, which enhances the receptor–analyte interaction. In addition, cellulose is renewable, biodegradable, nontoxic, biocompatible, industrially available at low cost, thermally stable, printable and able to form highly transparent, flexible and foldable films. Given the just

listed impressive features, cellulose stands out as a powerful alternative to replace petroleum-based polymers in the development of high-performance (bio)sensors.

- **Controlled/slow-release fertilizer based on cellulose composite and its impact on sustainable agriculture: review**

Aug 2022 | https://onlinelibrary.wiley.com/doi/full/10.1002/bbb.2433

Abstract

The increase in global population puts pressure on food supplies in the agricultural sector, whose productivity depends on the soil nutrient availability. This demand has an impact on the high chemical fertilizer consumption. Simultaneously, another problem arises owing to unsustainable agricultural practices, namely low fertilizer efficiency. Controlled/slow-release (CRF/SRF) fertilizers using cellulose biopolymers as composite matrices are a sustainable prospect owing to their being abundant, renewable, and biodegradable. Furthermore, cellulose contains surface chemical properties that are easily modified to play a role in the fertilizers' release. In addition, the high cellulose hydrophilicity helps maintain soil moisture for plant growth. This article reviews the prospects of cellulose and its derivatives for CRF/SRF development, including cellulose modification, slow/controlled-release mechanisms, and their impact on sustainable agricultural practices, which are discussed based on environmental, economic and social aspects. In addition, selecting environmentally friendly and low-cost technologies is a concern to support sustainability.

Agricultural Sensing & Monitoring

- **Spatio-Temporal Patterns of Crops and Agrochemicals in Canada Over 35 Years**

Nov 2020 | https://www.frontiersin.org/articles/10.3389/fenvs.2020.556452/full

In an effort to feed a growing world population, agriculture has rapidly intensified over the last six decades, relying heavily on agrochemicals (fertilizers, insecticides, fungicides, and herbicides) to increase and maintain desired crop yields. Despite environmental concerns in Canada's agricultural regions, long-term patterns of changing crops and the associated trends in the proportion of cropland treated with agrochemicals are poorly documented. Using the Canadian Census of Agriculture, we compiled historical data over 35 years (eight census periods: 1981–2016) on agrochemical applications, measured as the proportion of cropland treated with pesticides and fertilizers and the associated crop classes, to identify and interpret spatial and temporal trends in Canada's agricultural practices across 260 census units. Due to differences in agricultural practices, soil, and climatic conditions across the country, the Pacific (British Columbia), Prairie (Alberta, Saskatchewan, Manitoba), Central (Ontario, Quebec), and Atlantic (Nova Scotia, New Brunswick, Newfoundland/Labrador, Prince Edward Island) regions were analyzed separately. Most of the agrochemicals in Canada were applied in the Prairie and Central regions, which combined comprise 97% of the total cropland. Fertilizers were the dominant agrochemicals across Canada applied on 48% (Pacific) to 78% (Prairie) of the total cropland area, followed by herbicides, which were applied on 30% (Pacific) to 81% (Prairie) of the total cropland area in 2016. Notably, we observed significant changes between 1996 and 2016 in area treated with fungicides and insecticides, which increased by 412% and 50% in the Prairie region and by 291% and 149% in the Central region, respectively. The proportion and distribution of crops shifted in favor of more oilseeds and soybeans in the most intensive Prairie and Central regions, whereas cereals decreased over the same time period. Our analysis of past and current trends of agrochemicals and cropping patterns within Canada indicates a rapid and systemic increase in chemical use, and policies that promote a shift toward lower chemical reliance through sustainable agricultural practices are urgently needed.

► Worldwide pesticide usage and its impacts on ecosystem

Oct 2019 | https://link.springer.com/article/10.1007/s42452-019-1485-1

Abstract

Pesticides are extensively used in modern agriculture and are an effective and economical way to enhance the yield quality and quantity, thus ensuring food security for the ever-growing population around the globe. Approximately, 2 million tonnes of pesticides are utilized annually worldwide, where China is the major contributing country, followed by the USA and Argentina, which is increasing rapidly. However, by the year 2020, the global pesticide usage has been estimated to increase up to 3.5 million tonnes. Although pesticides are beneficial for crop production point of view, extensive use of pesticides can possess serious consequences because of their bio-magnification and persistent nature. Diverse pesticides directly or indirectly polluted air, water, soil and overall ecosystem which cause serious health hazard for living being. In the present manuscript, an attempt has been made to critically review the global usage of different pesticides and their major adverse impacts on ecosystem, which will provide guidance for a wide range of researchers in this area.

► Pesticide residues in food

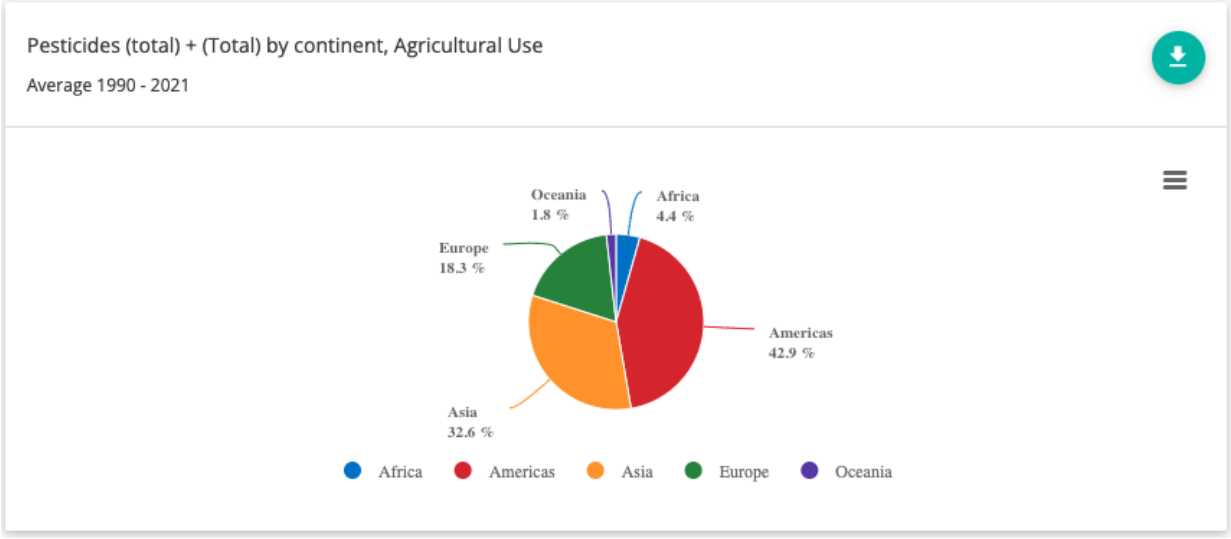
Sep 2022 | https://www.who.int/news-room/fact-sheets/detail/pesticide-residues-in-food#:~:text=There%20are%20more%20than%201000,different%20properties%20and%20toxicological%20effects

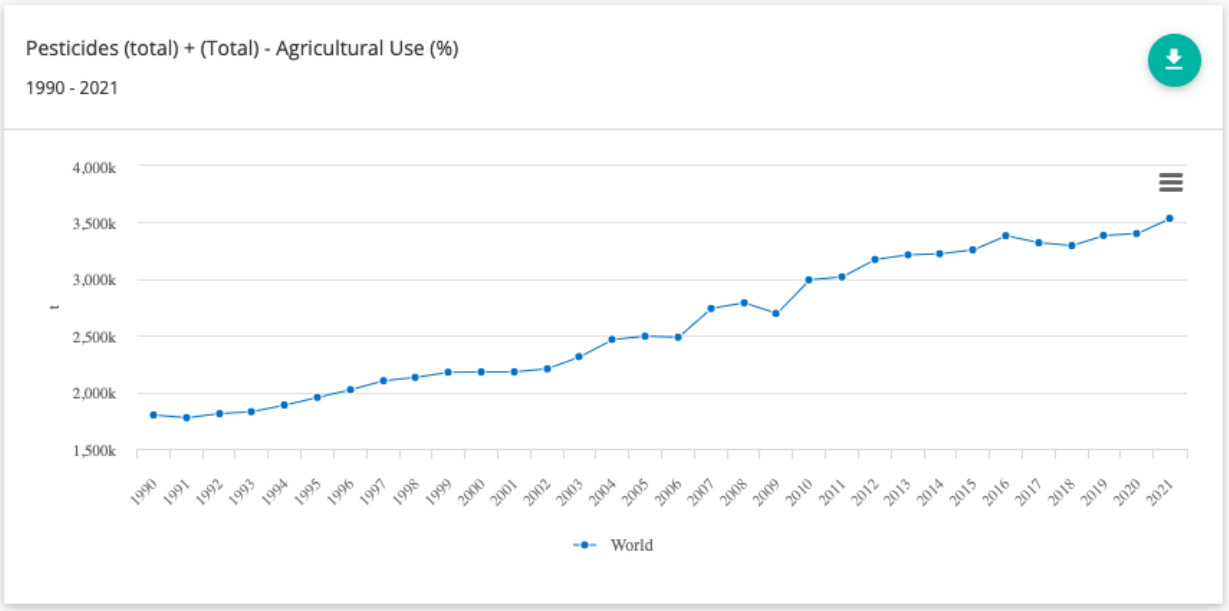
Overview

There are more than 1000 pesticides used around the world to ensure food is not damaged or destroyed by pests. Each pesticide has different properties and toxicological effects.

► Agricultural consumption of pesticides worldwide from 1990 to 2020(in million metric tons)

Jul 2022 | https://www.fao.org/faostat/en/#data/RP/visualize





The global agricultural consumption of pesticides grew mostly steadily from 1990 to 2020. In the latter year, pesticide consumption worldwide stood at nearly 2.7 million metric tons, an increase of more than 57 percent when compared to 1990.

► **Aflatoxin and Mycotoxin Analysis: An Overview Including Options for Resource-limited Settings**

Jul 2022 | https://www.intechopen.com/chapters/83520

Abstract

Aflatoxins are fungal toxins of serious human health concern, more so in some developing countries where significant contamination of staple foods occurs and the prevalence of aflatoxin-related health effects is high. A plethora of techniques for food mycotoxin testing has been developed. Modern chromatographic techniques allow quantitative determination with high accuracy and sensitivity, but are expensive and difficult to operate and maintain. Rapid tests provide a cheaper alternative for screening large numbers of samples, although they need validation on all food matrices that are tested. One important aspect of tackling aflatoxin contamination and exposure is to ensure the availability of suitable methods for detection and quantification that are rapid, sensitive, accurate, robust, and cost-effective for food surveillance in resource-limited settings.

1. Introduction

Food contamination with mycotoxins is a serious human health concern worldwide and of greatest significance in developing countries [1, 2]. Of all the mycotoxins, aflatoxins are more toxic, widespread in nature, and have been associated with significant health effects in humans and reduced productivity in farmed animals [3, 4, 5]. Recent estimates suggest that 60–80% of crops contain detectable concentrations of mycotoxins. In many instances, there is co-contamination with more than one toxin and this is geographically dependent on climate and farming practices [6, 7].

Aflatoxins affect approximately 4.5 billion people in developing countries, causing acute fatal hepatitis in individuals exposed to highly contaminated grains. Low level, chronic exposure to aflatoxins is associated with the development of liver cancer in adults, reduced immunity, and lowered growth and stunting in infants and children [8, 9, 10]. Monitoring food for contamination with aflatoxins is essential, although a number of challenges must be faced, including low concentrations and variable distribution of the toxin in

contaminated grains within storage facilities. These factors will contribute to variable test results as well as issues related to test sensitivity and specificity in varied food matrices [5, 11].

This chapter provides an overview of sample extraction and cleanup procedures, together with analytical techniques developed for mycotoxins, including aflatoxins. The advantages and disadvantages of the different approaches affecting suitability for use in aflatoxin food surveillance and quantitative confirmation are outlined. In developing countries, rapid tests make a significant contribution to aflatoxin control and a perspective on their application in resource-limited settings is given.

2. General mycotoxin analytical techniques

Mycotoxins present a great analytical challenge. Not only do they include a diversity of chemical compounds, but are heterogeneously distributed at varying concentrations in a wide range of agricultural commodities, foods, feeds, and biological samples that require specific extraction, cleanup, separation, and detection methods [11]. Some mycotoxins, especially deoxynivalenol and zearalenone, are conjugated as a result of plant metabolism, and these "masked" mycotoxins may contribute 20% of total of the parent mycotoxin but are not detected during conventional analysis [5, 11].

Quantification of mycotoxins requires expensive laboratory equipment that needs well-trained personnel to operate [12], as well as involving a series of steps and procedures that may be laborious and time-consuming [11]. The need for high sensitivity tests to detect the minimum levels of the mycotoxin possible for regulatory purposes, coupled with rapidity, high accuracy, simplicity, robustness, and selectivity have been the main driving forces behind the improvement and development of new mycotoxin analytical protocols [11, 13]. Mycotoxin analysis is essential to quantify the toxin for risk evaluation, diagnosis, and monitoring mitigation strategies [5].

6.1 Conventional analytical techniques

Conventional analytical methods employ chromatographic separation, particularly, liquid chromatography (LC), thin layer chromatography (TLC) and gas chromatography (GC) coupled to a detection system, with high-performance liquid chromatography (HPLC) after immunoaffinity cleanup combined with fluorescence detection (FLD) or mass spectrometry (MS) frequently employed for the quantitative determination of regulated mycotoxins in food [11, 18].

6.1.1 Thin layer chromatography

Thin layer chromatography (TLC) was traditionally the most widely used mycotoxin screening technique that did not require expensive equipment and enabled high sample throughput [23]. The TLC techniques lack separating power that limits discrimination of co-extracted interference from the analyte of interest. This may, however, be overcome through improved modern cleanup techniques that remove impurities [12].

6.1.2 High-performance liquid chromatography

High-performance liquid chromatography (HPLC) is now most commonly used for mycotoxin determination offering good sensitivity and precision, coupled with ease of automation [12, 19]. After extraction and cleanup, samples are injected into the HPLC column, individual compounds are separated based on their affinity for the column matrix and the mobile phase solvent [27]. To enhance fluorescence for better mycotoxin quantification using the HPLC-FLD technique, derivatization is important [12]. Pre-column derivatization with trifluoroacetic acid (TFA), or post-column derivatization, with bromine or iodine, can be used to identify aflatoxins [17]. Photochemical post-column derivatization may provide a cheaper alternative, whereas specific cyclodextrins may be incorporated in the mobile phase for non-chemical enhancement of fluorescence [28]. Despite offering good sensitivity and specificity, HPLC-FLD techniques

are limited by expensive equipment requiring operation by experienced staff and may require laborious sample preparation procedures [12, 19].

Recent utilization of ultra-HPLC (UHPLC) methods that are based upon increasing the mobile phase pumping pressure up to 1000 bar and above and reduction of particle size from 5 µm (HPLC) to 1–2 µm (UHPLC) improves resolution, sensitivity, and achieves rapid chromatographic separation as a result of increased speed and resolution between analytes [39, 40]. However, to avoid the high cost of the UHPLC system, columns packed with materials having solid core particles, coated with an outer layer of porous material can achieve more efficient separations at a much faster rate than with standard columns eliminating the need for expensive high-pressure facility because they are able to work at standard pressures (up to 600 bar) and can be used on all HPLC systems [41].

6.1.3 Liquid chromatography/mass spectrometry

Liquid chromatography with mass spectrometry (LC/MS) is a technique that allows more sensitive and selective determination of multiple mycotoxins in complex matrices with improved limits of detection and quantification [27]. Atmospheric pressure chemical ionization (APCI), atmospheric pressure photo ionization (APPI), and electrospray ionization (ESI) interfaces are currently employed in modern LC/MS instrumentation owing to their robustness, easy handling, high sensitivity, accuracy, and analyte selectivity and compatibility to a wide range of compound polarities [22, 42].

Liquid chromatography coupled to high-resolution mass spectrometry (LC-HRMS) equipment has been developed that can significantly increase the sensitivity and specificity of multi-mycotoxin assays [37].

Liquid chromatography with tandem mass spectrometry (LC-MS/MS) has been increasingly used to provide a simultaneous determination of different classes of mycotoxins, including the regulated mycotoxins, thus affording to increase sample throughput and decreasing the cost per analysis [11]. However, given the complexity of matrixes to be analyzed and the wide-ranging physical and chemical mycotoxin properties, such methods require great skill to develop [11, 22, 42].

Mass spectrometry detectors linked to HPLC, UHPLC, and GC systems can increase their separation and identification power. However, the MS facilities are expensive with complex laboratory requirements, require skilled operators, and may suffer solvent limitations [23].

6.1.4 Gas chromatography

Gas chromatography (GC) may be used to determine mycotoxins that are volatile within the column [19]. For example, GC coupled with electron capture detection (ECD), flame ionization detection (FID) or mass spectrometric detection (MS) may be used for trichothecene or patulin determination. However, when compared to alternative methods, GC requires prior cleanup of extracts and pre-column derivatization to increase the volatility and sensitivity of the toxins [11, 17]. Although having successful applications, GC has several disadvantages that include the analyzed sample to be volatile or converted into a volatile sample, problems with the thermal stability of the sample leading to losses, and the high cost of the equipment [23].

6.2 Rapid screening methods

Rapid screening methods, that include immunochemical techniques, varying from simple lateral flow and enzyme-linked immunosorbent assays (ELISA) to highly sophisticated immunosensors, are based upon binding of an antigen, for example a mycotoxin to a specific antibody, and often do not require any cleanup or analyte enrichment steps [11, 18, 43].

6.2.1 ELISA techniques

The enzyme-linked immunosorbent assay (ELISA) technique utilizes a specific antibody to bind the target molecule directly or conjugated with the enzyme and interaction with a chromogenic substrate to give a

measurable result [18, 23]. However, due to the low molecular weight of mycotoxins, they are not immunogenic and must be conjugated to a carrier molecule to achieve immunogenicity. The ELISA technique can be highly sensitive and specific, portable, rapid, and simple to use with high sample turnover. However, ELISA has a number of disadvantages that include single-use kits that can increase the cost of bulk screening, high matrix dependence, cross-reactivity, and limited detection range due to the narrow sensitivity of the antibodies [13, 23].

6.2.2 Immunosensor/biosensor techniques

Biosensors are based upon the interaction of a mycotoxin with a recognition system fabricated as a layer onto the surface of a matrix substance that induces a change that is converted into a measurable electronic signal by a transducer. This provides great sensitivity and selectivity, easy application, low cost, and portability [27, 44]. Biosensors are often classified by the type of toxin-binding element (e.g., antibody, aptamer, imprinted polymers, etc.) as well as by the technology used for signal transduction and detection (e.g., optical, electrochemical, piezoelectric, etc.) [33].

A number of biosensor/immunosensor assays and techniques have been developed for mycotoxin determination, including fiber optic devices, surface plasmon resonance (SPR), dip-stick and lateral flow devices, fluorescence polarization, time-resolved fluorescence, microbead, capillary electrophoresis (CE), and electrochemical and piezoelectric immunoassays [45, 46]. These techniques are outlined in the following subsections.

6.2.2.1 Optical biosensors and fiber optic devices

Optical sensors, based on a variation of optical signals generated by a transducer from molecular recognition events on a sensing element are divided into many subclasses depending on the type of signal generated, including calorimetric, fluorescent, chemiluminescent, and surface plasmon resonance [35]. Photoelectrochemical optical biosensors use light as an excitation source and photocurrent as the recognition signal, whereas another subset of optical biosensors uses total internal reflection ellipsometry with localized surface plasmon resonance for detection with an optical planar waveguide polarization interferometer [33]. For example, fluorescent-based fiber optic devices can capture fluorescence emission from the fluorescently labeled mycotoxin or the naturally fluorescent mycotoxin, for example, aflatoxin when they bind to the fiber optic surface and transmit it to a sensitive detector [45]. A commercial device "Octet" based on biolayer interferometry to detect changes in the interference pattern of light reflected from the surface of optical fiber when materials bind to the tip of the fiber has been developed and available from ForteBio (Menlo Park, Calif., USA) [47, 48].

6.2.2.2 Surface plasmon resonance

The SPR technique is based upon the property that the binding of materials to a surface, for example, the binding of antibodies to the mycotoxin, can alter the refractive index near that surface. The SPR device measures the small changes in the angle, or intensity, of internally reflected light that results from the binding event, and the magnitude of the response is influenced by the amount of material adhering to the surface. Alternatively, surface plasmons may be used to excite fluorophores captured on a surface, a technique is known as surface plasmon-enhanced fluorescence spectroscopy (SPFS). With this technique, light is used to excite plasmons (electron charge density waves) in a thin film of gold foil attached to the surface of a glass prism, the resonance of which enhances the fluorescence of the captured fluorophores, for example, the labeled antibody [45, 46, 49]. Using imaging, SPR (iSPR) allows multiple binding events on different regions of the sensor surface to be monitored simultaneously (multiplexing), hence capable of measuring multiple antigen-antibody interactions simultaneously in a single injection [49, 50].

The advantages of SPR include rapid and simple cleanup procedures, short analysis times, reusable sensor chips, and not necessarily requiring competition or labeled reagents for detection. It has great potential for

multiplexing, with a wide variety of commercially available devices [46, 49]. However, like most immunoassays, SPR can be influenced by matrix effects that can be dealt with by increasing the dilution of the sample extract or by cleanup of the extract before the detection step [46].

6.2.2.3 Lateral flow devices

Lateral flow strip and dipstick devices (immunochromatographic test devices) use rapid disposable devices that may be attached with the toxin or the antibody that can bear enzymatic, liposome associated, or colloidal gold labels to detect the presence of mycotoxins [45]. Colloidal gold is frequently used as a label in test strips developed for mycotoxins due to availability, ease of production, and ease of conjugate formation with antibodies [51]. "Mycotoxin in the sample extract interacts with colloidal gold conjugated anti-mycotoxin antibodies at the base of the stick, with both bound and unbound antibodies moving along the stick membrane, passing a test line composed of immobilized mycotoxin, which will bind free antibody to form a visible line indicating a level of aflatoxin contamination below the test cut-off value. The control line further along the stick is composed of anti-antibodies to ensure complete extract migration along the strip" [28].

The related, membrane-based flow-through device, also known as enzyme-linked immunofiltration assay (ELIFA) differs from lateral flow devices, in that the applied liquid flows perpendicularly through the membrane rather than laterally, where it is collected on an absorbent pad on the opposite side of the membrane. It uses an enzymatic label that requires a substrate-incubation step, with the test and control lines being generated by an enzyme-substrate color reaction [28, 45].

Because of their easy application, efforts to develop dipstick and lateral flow assays for mycotoxins are likely to continue, particularly using stable, nonenzymatic labels [45], with a number of devices already being commercially available [17]. Also, innovative labels based on nanoparticle applications, such as quantum dots (QDs), gold nanoparticles (AuNPs), magnetic nanoparticles (Fe_3O_4), carbon nanoparticles (CNPs), time-resolved fluorescent microspheres (TRFM), have been developed for signal amplification in LFD, which can improve detection. Moreover, the advent of a fluorescence quenching principle in lateral flow immunoassays (LFIA) in contrast to traditional competitive LFIA increases the sensitivity of the LFIA [35, 52].

6.2.2.4 Fluorescence polarization and time-resolved fluorescence

Fluorescence polarization (FP) immunoassays are solution-phase assays that rely on the measurement of change in the rate of rotation of a fluorescent-labeled mycotoxin (tracer) when it forms an immune complex with the added antitoxin antibody after competing with unlabeled mycotoxin in the sample extract [28, 45, 46]. FP can be used to measure the rate of association of the toxin with the antibody (kinetic assays) or the equilibrium point in a competition reaction (equilibrium assays). Critically, FP relies on the proper selection of antibody and tracer pairs [45, 46].

Unlike FP immunoassays, time-resolved fluorescent immunoassays (TR-FIA) use the property of fluorescence lifetime to measure the rate of decay of a fluorophore that is associated with a mycotoxin [45]. The newer fluorescent materials known as lanthanides, such as Eu (III) and Tb (III), have much longer fluorescence lifetimes that can eliminate the background fluorescence interference from the matrix, thus improving the sensitivity of methods based on TR-FIA [35].

The fact that FP is a homogeneous assay that does not require the separation of the free and bound tracer, may eliminate additional steps, such as washing, in competitive ELISA, thus increasing method rapidity [53]. However, like most immunoassays, it can be affected by the presence of a matrix, which can be controlled through dilution, cleanup, matrix-matched calibration curves, or data normalization [46, 53]. Although the available FP immunoassay readers are not capable of multi-mycotoxin detection, the potential speed of FP assays combined with the portability of the devices, suggests this technology has a promising future [46].

6.2.2.5 Microbead assays

Microbead assays use antibodies or antigens attached to the microbeads in miniaturized IAC assays, often with the cleanup and detection steps performed on a single instrument. It can be affected by poor re-usability of the columns due to fouling and reduced functional capacity of antibodies [45].

6.2.2.6 Capillary electrophoretic immunoassays

Capillary electrophoresis (CE) employs capillaries that are injected with the cleaned sample extracts in aqueous buffer solutions where they are separated in an electrical field before detection, typically using fluorescence or UV absorbance [23, 45]. The CE methods have comparable sensitivity, precision, and accuracy to HPLC methods, use less expensive capillaries, eliminate the use of organic solvents and take shorter analysis times, thus making them viable alternatives to HPLC [17].

6.2.2.7 Electrochemical immunosensor assays

Electrochemical immunosensors for mycotoxin determination are based on the high-affinity interaction between antigen and specific antibodies that can be transformed into a measured electrochemical signal based on a variety of electrochemical techniques [54]. They can be categorized into amperometric, potentiometric, conductometric, impedimetric, and voltammetric sensors according to the types of detectable electrical signals [35]. In their simplest format, the immobilized antibody is bound to the surface of a screen-printed electrode, and the final enzymatic stage develops a reaction product that can be measured by its electrical properties [28].

These electrochemical assays can be affected by factors that influence the interface between antigen and antibody, including solvent-matrix interactions and the reduction/oxidation potential of the diluent. The extent of testing using this technology, the accessibility of components, and the capacity for miniaturization, suggest future utility of these devices in the detection of aflatoxins [46].

6.2.2.8 Piezoelectric sensors

Piezoelectric sensors often called quartz crystal microbalance (QCM) are based upon piezoelectric quartz crystals and they work through the application of an alternating current to a quartz crystal, which induces oscillations of the crystal, the frequency of which depends in part on the thickness of the crystal, for example, after mycotoxin binding on immobilized antibodies [46]. Mass change on the sensory layer of the surface of the gold-plated crystal quartz transducer causes specific measurable vibrations of the crystal in response to an electrical signal [20]. The advantage of QCM is that they do not require the use of labeled reagents [46].

In general terms, immunochemical techniques are affected by high matrix dependence, cross-reactivity, and loss of antibody stability under the extreme environment, such as pH, organic solvents, and high temperature. Moreover, the cost of their development may be high and requires a stable source of antibodies to ensure continuity of analytical performance and stability. Therefore, the development of synthetic receptors can solve some of these challenges, particularly, problems associated with antibody stability in an extreme environment [18, 44, 54]. As an example, [55] developed an aptamer-based assay for the detection of AFB_1 in corn samples that exhibited a wide dynamic range from 0.1 to 10 ng/mL, limit of detection of 0.11 ng/mL, and recovery values between 60.4 and 105.5% that were described as promising results.

It is worthy to note that, chemical and biochemical sensor devices are increasingly developed based on advanced microchip technology, including microfluidic chips and microarrays for portability, easy on-site field application, robustness, reliability, reduced cost, rapidity, high throughput, and increased sensitivity. Also, the advent of innovative labels based on nanoparticle application has led to a significant improvement in their detection capability. Examples of these include the microfluidic devices based on flow-through (capillary electromigration) and lateral flow formats and the emerging microchip-based sensing methods, such as surface plasmon resonance (SPR) and magnet nonotag-based detection [35, 56, 57].

6.3 Noninvasive techniques

Noninvasive techniques, such as spectroscopic and imaging techniques [27], DNA microarrays, electronic chemical sensors (electronic nose and tongue), and polymerase chain reaction-based methods [27, 44] provide a potential approach for rapid nondestructive detection of fungal infection and mycotoxin contamination on grains. However, many of these techniques may either be expensive and/or may need further validation studies.

7. Conclusions and analysis in resource-limited settings

All components of the food supply chain can become contaminated with aflatoxins and other mycotoxins. For food to meet safety standards, and for the development of mitigation strategies, determination of the degree of contamination is required. Analytical procedures for aflatoxin detection and quantification remain central to resolving this important food and feed safety issues. The many issues surrounding robust mycotoxin analysis have been addressed in a number of books [58, 59, 60, 61] that the interested reader may wish to consult.

Since the discovery of aflatoxins, there has been a huge international effort to develop appropriate analytical procedures. However, all techniques have had to overcome a number of significant problems, including:

Diverse chemical structures that require individual methods for different mycotoxins;

Separation of structurally similar compounds;

Mycotoxins occur in very low concentrations in different commodities, thus removal or cleanup of the food/feed matrix is required. Each commodity may require a different cleanup procedure;

Due to the uneven distribution of mycotoxins in a commodity, it is important to analyze many samples that have been collected using a validated sampling plan.

As is apparent in this chapter, there are a plethora of approaches, both quantitative and qualitative, for aflatoxin analysis that overcame these problems. The advantages and disadvantages of the different analytical approaches are listed in Appendix 1 and examples of biosensor platforms for mycotoxin detection and their performance in terms of limit of detection is given in Appendix 2. Although, the conventional analytical techniques, particularly HPLC linked to the mass spectrometer or fluorescent detectors are indispensable to confirm the quantities of contamination and for determining the chemical identity of the various groups of mycotoxins, equipment is very expensive and there are ongoing instrument maintenance and solvent costs, and specially trained analysts are required. However, these techniques do not apply to resource-limited settings. The initial technique used for aflatoxin analysis was TLC, and it is still used in many laboratories, especially in developing countries, as it does not require expensive laboratory equipment.

The development of screening methods that provide rapid, low-cost analysis of large number of samples is required for food surveillance, particularly in low-income countries. For the most part, screening methods are specific, sensitive, and relatively simple to operate. There is also a need in low-income rural communities for rapid screening methods, where an electrical supply is often unavailable [62]. ELISAs and dipstick/lateral flow devices are simple to operate and are used widely in developing countries. However, before use, operators need to be confident that the assay kit is “fit for purpose,” and is appropriate for the commodity matrix to be tested [62]. If the assay kit is not valid for the commodity tested, cross-reactivity may occur and the number of the false positive sample will increase. There are increasing efforts to develop multi-toxin screening assays, as aflatoxin is often found in association with other mycotoxins, including fumonisins and deoxynivalenol [6]. This information is important, as it is essential to know the extent of toxin exposure so the appropriate public health and mitigation steps can be undertaken. Finally, it is very

important that the results obtained in the field with rapid screening tests give comparable results to quantitative analysis in regulatory laboratories.

Structural Materials

- **Agriculture: Super Absorbent Functional Polymers**

Aug 2019 | https://www.routledgehandbooks.com/pdf/doi/10.4324/9781351019422-140000356

Abstract

Superabsorbent polymer (SAP) material has raised great involvement since sustainable evolution policies tend to extend with the reduced irrigation frequency, overuse of fertilizer, and enhanced water-holding capacity in the soil. These SAPs bring a significant contribution role to the agricultural development in the way plant growth. Polysaccharide and polypeptide-based SAPs are produced from renewable resource or fully synthetic-based SAPs from petroleum resources. In general, biopolymer-based SAPs are degradable by microorganism as well as fully synthetic SAPs. This chapter describes the overview of the semi-synthetic (polysaccharide- and polypeptide-based SAPs) and fully synthetic SAPs that are recently being used in agriculture application as well as various types of evolution in their synthesis process.

- **Functional nanomaterials to augment photosynthesis: evidence and considerations for their responsible use in agricultural applications**

Dec 2018 | https://royalsocietypublishing.org/doi/10.1098/rsfs.2018.0048

Abstract

At the current population growth rate, we will soon be unable to meet increasing food demands. As a consequence of this potential problem, considerable efforts have been made to enhance crop productivity by breeding, genetics and improving agricultural practices. While these techniques have traditionally been successful, their efficacy since the 'green revolution' has begun to significantly plateau. This stagnation of gains combined with the negative effects of climate change on crop yields has prompted researchers to develop novel and radical methods to increase crop productivity. Recent work has begun exploring the use of nanomaterials as synthetic probes to augment how plants use light. Photosynthesis in crops is often limited by their ability to absorb and exploit solar energy for photochemistry. The capacity to interact with and optimize how plants use light has the potential to increase the productivity of crops and enable the tailoring of crops for different environments and to compensate for predicted climate changes. Advances in the synthesis and surface modification of nanomaterials have overcome previous drawbacks and renewed their potential use as synthetic probes to enhance crop yields. Here, we review the current applications of functional nanomaterials in plants and will make an argument for the continued development of promising new nanomaterials and future applications in agriculture. This will highlight that functional nanomaterials have the clear potential to provide a much-needed route to enhanced future food security. In addition, we will discuss the often-ignored current evidence of nanoparticles present in the environment as well as inform and encourage caution on the regulation of nanomaterials in agriculture.

- **Biomaterials Technology for AgroFood Resilience**

May 2022 | https://onlinelibrary.wiley.com/doi/full/10.1002/adfm.202201930

Abstract

This review article highlights recent advances in designing biomaterials to be interfaced with food and plants, with the goal of enhancing the resilience of the AgroFood infrastructure by boosting crop production, mitigating environmental impact, and reducing losses along the supply chain. Special attention is given to innovations in biomaterial-based approaches and platforms for 1) seed enhancement through

encapsulation, preservation, and controlled release of payloads (e.g., plant growth-promoting microbes) to the seeds and their rhizosphere; 2) precision delivery of multi-scale payloads to targeted plant tissues, organelles, and vasculature; 3) edible food coatings that regulate gas exchanges and provide antimicrobial properties to extend the shelf life of perishable food; and 4) food spoilage detection based on different sensor/reporter systems. Within each domain, biomaterials design principles, emerging micro-/nanofabrication strategies, and the advantages and disadvantages of different delivery/preservation/sensing platforms are introduced and critically discussed. Views of future requirements, aims, and trends are also given based on the opportunities and challenges of applying biomaterials in the AgroFood system.

- **Recent development in functional nanomaterials for sustainable and smart agricultural chemical technologies**

Dec 2022 | https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8891417/

Abstract

New advances in nanotechnology are driving a wave of technology revolution impacting a broad range of areas in agricultural production. The current work reviews nanopesticides, nano-fabricated fertilizers, and nano activity-based growth promoters reported in the last several years, focusing on mechanisms revealed for preparation and functioning. It appears to us that with many fundamental concepts have been demonstrated over last two decades, new advances in this area continue to expand mainly in three directions, i.e., efficiency improvement, material sustainability and environment-specific stimulation functionalities. It is also evident that environmental and health concerns associated with nano agrochemicals are the primary motivation and focus for most recent work. Challenges and perspectives for future development of nano agrochemicals are also discussed.

Keywords: Nanotechnology, Nanomaterial, Agrochemical, Nanopesticide, Nano-fabricated fertilizer, Nano activity-based growth promoter

Introduction

The rapidly growing demands in sustainable economy set forth grand challenges to current agricultural industry that have traditionally relied heavily on agrochemicals, including synthetic pesticides and fertilizers. Up to now, the global use of pesticides and fertilizers have reached over 4.1 and 125 million tons, respectively [1, 2]; however, the traditional way of administering agrochemicals is generally inefficient. For pesticides, which are generally synthetic organic compounds with high hydrophobicity and often poor chemical stability, it is estimated that only less than 1% of the applied dosage served the purpose, while the majority get lost to environment via volatilization, degradation, and photolysis in traditional application scenarios [3, 4]. A similar efficiency is also estimated for conventional fertilizers, which provide essential macronutrients (N, P, K, Mg, Ca, S, Si) and micronutrients (Fe, Cu, Zn, Mn, B, Mo, Ni, Na, Cl) for plant growth [5]. For example, volatilization and leaching could take away over 50% of nitrogen (N) content in traditional fertilizers [6]. Such a low efficiency not only increased the cost of production, but also generated widely concerned environmental and health impacts [7]. Reducing the amount and improving the use efficiency of agrochemicals by applying smart and precision agricultural technologies have therefore attracted extensive research interests [8], and release behavior control, chemical stability retention, and targeting capability are the fundamental pursuits, where nanotechnology is playing a crucial role [7, 8].

Nanotechnology focuses on synthesis, manipulation and functionalization of nanomaterials [9]. Nanotechnology has made great impacts in recent advances in all the major technological areas including biomedical engineering, food science, IT, etc. [10–19]. For precision agriculture, agrochemicals prepared in different formats of nanomaterials promise a variety of appealing characteristics, including controlled and stimulation-regulated release rate, location- or time-specific targeting, long-term stability and duration,

increased solubility, enhanced compatibility, etc. [7, 8]. Both structural design and material composition of the nanomaterials can be manipulated for optimal in-field functionality and activity, affording the technology sustainability and precision characteristics (Fig. 1). Agricultural nanotechnologies have been proposed and substantially examined over the last two decades, with tens of reviews published from various perspectives. This review will focus mostly on research published in the last five years, examining new advances in synthetic strategies, functionalities, and applications of nanoscale agrochemical technologies. It appears that nano-fabricated pesticides and fertilizers for improved field efficacy continued to be the focus in recent years. Attention is particularly evident on topics such as material selection, preparation optimization, structural design, and stability enhancement, toward sustainability and environmental considerations. These will be discussed in the first two parts of the review. At the same time, a growing interest has also been found in developing biologically active nanomaterials, instead of nanocarriers of other active or nutritional agents, to promote crop growth, seed germination, insect resistance, microenvironmental regulation, etc. This aspect will be discussed in the third part. Analytical nanotechnologies such as those targeting pathogen and pesticide/herbicide residue detections constitute another major category of nanotechnologies for agricultural production, and have been reviewed previously [20–27], will not be covered in this work.

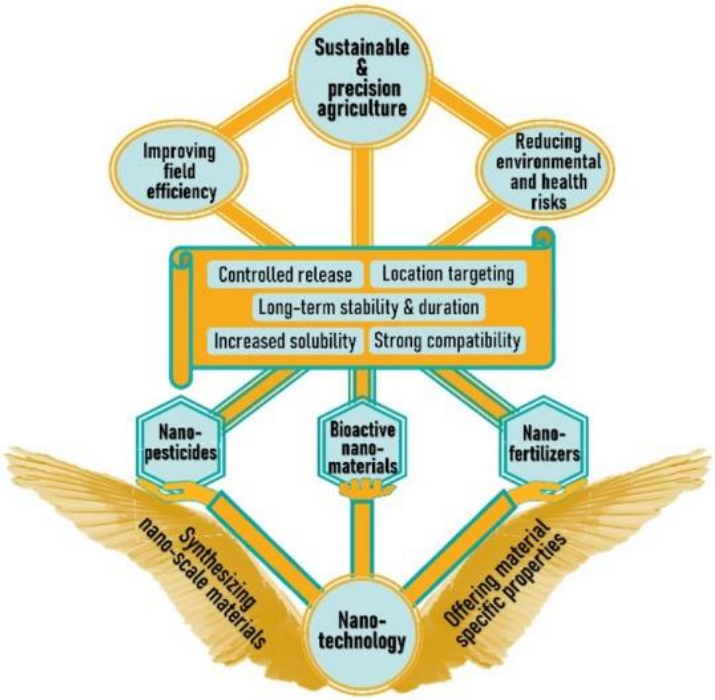


Fig. 1

Topics and Concepts Entailed in Nanoscale Agrochemicals for Sustainable and Precision Agriculture Technologies

- **Recent progress in the conversion of biomass wastes into functional materials for value-added applications**

Nov 2020 | https://www.tandfonline.com/doi/full/10.1080/14686996.2020.1848213

ABSTRACT

The amount of biomass wastes is rapidly increasing, which leads to numerous disposal problems and governance issues. Thus, the recycling and reuse of biomass wastes into value-added applications have attracted more and more attention. This paper reviews the research on biomass waste utilization and biomass wastes derived functional materials in last five years. The recent research interests mainly focus on the following three aspects: (1) extraction of natural polymers from biomass wastes, (2) reuse of biomass wastes, and (3) preparation of carbon-based materials as novel adsorbents, catalyst carriers, electrode materials, and functional composites. Various biomass wastes have been collected from agricultural and forestry wastes, animal wastes, industrial wastes and municipal solid wastes as raw materials with low cost; however, future studies are required to evaluate the quality and safety of biomass wastes derived products and develop highly feasible and cost-effective methods for the conversion of biomass wastes to enable the industrial scale production.



- **Development of sustainable alternative materials for the construction of green buildings using agricultural residues: A review**

Mar 2023 | https://www.sciencedirect.com/science/article/pii/S095006182300168X

Highlights

- Sustainable and Green Building Materials that can be used in construction.
- Strategies and concept of sustainable building material with environmental approaches.
- Agricultural residues as an alternative material in construction and buildings.
- A techno viable solution using agro-waste in green building constructions.
- Low carbon credit and ecological green buildings.

Abstract

The development of the construction sector has created a deficit and constraints on natural building materials. The ecological impact of the construction material has been the subject of several investigations. About 40% of all CO_2 emissions originate from the construction and use of buildings, 15% of which are associated with the production of construction materials. Therefore, it has been critical that the construction industry shift towards a greener approach to building construction. In addition, the excessive use of natural

and river sand (likely used as fine aggregate in concrete) adversely affects environmental sustainability. In addition, the generation of agricultural residues/agro-waste imposes adverse ecological effects. Agro-waste is inevitably generated and burned after harvest to clean up the landfill. Agro-waste such as paddy husk, sugarcane, and red gram crops generate 10–15 times more than the actual products. Indeed, to meet the demand for building construction materials, it is preferably necessary to adopt native and eco-friendly alternate construction materials. Agro-waste has shown the perspective of sustainable alternative materials to be applied in building constructions. In this work, we have deliberated the various potential applications of agro-waste in building constructions. Also, we have conferred the evaluation of the physical, thermo-mechanical, methodological, and ecological impact. The application of agricultural wastes has been demonstrated to be a commercially viable technological solution for building construction materials that could ease the use of natural resources with energy safety.

