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Review Article on Agro Textiles: The Future of Farming

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ABSTRACT
Agro textiles are one of the twelve categories of technical textiles, primarily utilized in agriculture, horticulture, forestry, and aquaculture. These textiles have been used in agriculture for thousands of years, providing effective crop protection throughout their entire life cycle. The current agro textiles market is mainly comprised of polyolefin and petrochemical-based products.Agro textiles are innovative products that are specially designed for the agricultural applications and practices. With the increase in population worldwide, stress on agricultural crops has increased.[2] As agriculture and horticulture look toward the future, they are adopting various technologies to enhance overall yield and product quality. Agro textiles such as sunscreens, bird nets, wind shields, mulch mats, hail protection nets, and harvesting nets are employed to achieve these objectives.

KEYWORDS: Agro-textile, Natural fibers, Synthetic fibers, Man-made fibers, Agro textile application, Decade of innovation, Market highlights

1. INTRODUCTION

Agro-textiles include textiles manufactured with agriculture motives. The Agro-textile segment is one of the fastest-growing segments of technical textiles.[8] Agro textiles mark a significant breakthrough in agricultural technology, addressing the evolving needs of modern farming. These specialized fabrics are vital for boosting crop production and efficient soil management. They encompass protective nets that safeguard plants against adverse weather and pests, and mulching fabrics that retain moisture and curb weed growth. Engineered for enhanced efficiency and sustainability, agro textiles enable farmers to increase yields, minimize resource consumption, and respond to environmental challenges. Ultimately, these innovative materials propel advancement in agriculture.Agro textile or Agro-tex are the textile materials which are either woven, knitted or non-woven technical textile which are primarily employed to protect the plant and animal from environmental factors and to enhance the yield of the crops.Agro-industry are nothing but different textile material used in agriculture and allied sectors like floriculture, forestry, landscape gardening, horticulture, fishing, animal husbandry and aquaculture.

2.1 AGRO TEXTILE

2.1.1 Natural fibers

Natural fibers are materials derived from plants, animals, or minerals that can be spun into yarn or used in their raw form. In general, researches on natural fibers represent further advances in sugarcane, coconut, banana, and pineapple, which are already employed as fibers in these studies. Materials such as açai, rice, wheat, and corn are highlighted for obtaining the raw fiber of the material, especially for reinforcing composites.[3]

2.1.1.1 COTTON

Cotton fiber is a natural fiber derived from the cotton plant, primarily from the seed fibers. Cotton is used in crop covers, mulch mats, and erosion control fabrics.Cotton fabrics can be used as row covers to protect plants from frost, pests, and harsh weather conditions. They allow light and moisture to penetrate while providing a barrier against insects. Its breathable nature helps in regulating soil temperature and moisture. Biodegradable and provides good insulation for plant roots.While cotton is effective, it may not be as durable as synthetic agro textiles in certain conditions. However, advancements in treatment and blending with other fibers are improving its longevity.

2.1.1.2 JUTE

Jute fiber is a natural, biodegradable fiber obtained from the jute plant, primarily the species *Corchorus capsularis* and *Corchorus olitorius*. It's known for its strength, durability, and versatility, making it a popular choice for a variety of products. Jute is popular for making Aro-textiles, erosion control blankets, and weed control fabrics. It is also used in silt fences and for soil stabilization.Jute agro textile is a kind of natural technical textile, usually either in woven or non-woven form, made from 100% natural eco-friendly bast fibre of jute plant used on soil to achieve higher agricultural productivity by improving agronomic characteristics of soil and by reducing growth of unwanted vegetation.[6]

Benefits: Highly biodegradable and affordable. It also has good water absorption properties.

2.1.1.2 HEMP

Hemp fiber is a versatile natural fiber derived from the stalks of the hemp plant, scientifically known as *Cannabis sativa*. Renowned for its strength and durability, hemp has been used for thousands of years across various cultures for a wide range of applications. Hemp fibers are used in soil erosion control, weed suppression, and in making durable agro-textiles like nets and ropes.

Benefits: Strong, durable, and eco-friendly. Hemp also grows quickly and requires minimal pesticides.

2.1.1.3 SISAL

Sisal fiber is a natural fiber obtained from the leaves of the sisal plant, scientifically known as *Agave sisalana*. It is primarily grown in tropical and subtropical regions and is known for its strength and durability. Sisal fibers are used in erosion control, soil stabilization, and as a component in composite materials for agro-textiles.

Benefits: Durable, resistant to decay, and biodegradable.

2.1.1.4 FLAX (LINEN)

Flax fiber is a natural fiber derived from the stalks of the flax plant, scientifically known as *Linum usitatissimum*. Known for its versatility and strength, flax fiber is primarily used to produce linen, one of the oldest textiles in the world. Flax fibers are used in soil stabilization, erosion control, and in making various types of agro-textile products.

Benefits: Strong and biodegradable. Flax requires fewer pesticides compared to other crops.

2.1.2 SYNTHETIC FIBER

Synthetic fibers are man-made materials produced from polymers and are widely used in agro-textiles for their durability, versatility, and specific performance characteristics.

2.1.2.1 POLYPROPYLENE (PP)

Polypropylene (PP) is a versatile thermoplastic polymer widely used in various applications due to its strength, chemical resistance, and flexibility. Polypropylene is used in a variety of agro-textiles including weed control fabrics, erosion control mats, and ground covers. It's also used in making geo textiles and drainage fabrics.

Benefits: Lightweight, resistant to water and chemicals, strong, and has good UV resistance. It's also cost-effective and has a long lifespan.

2.1.2.2 POLYESTER

Polyester fiber is a synthetic fiber made from polyethylene terephthalate (PET), a type of plastic derived from petroleum. It is one of the most widely used fibers in the textile industry due to its versatility, durability, and ease of care. Polyester fibers are used in soil stabilization fabrics, erosion control blankets, and crop protection nets. They are also used in high-strength geo textiles and anti-erosion meshes.

Benefits: Durable, resistant to UV degradation, and maintains its strength over time. Polyester also offers good dimensional stability and resistance to abrasion.

2.1.2.3 NYLON

Nylon fiber is a synthetic polymer that was first introduced in the 1930s by DuPont. Known for its strength, elasticity, and resistance to abrasion, nylon has become a widely used material in various industries. Nylon is used in high-strength agro-textile applications such as ropes, nets, and support structures. It is also employed in some erosion control and soil stabilization products.Nylon resists abrasion very well so it is suitable for nets which are dragged along the bottom. It is widely used for trawls of all kinds, seines, long and also ropes.Staple fiber twines made from poly-amides are not as strong as continuous filament twines but they are less stiff.[1]

Benefits: Extremely strong, elastic, and resistant to wear and tear. Nylon also has good resistance to environmental conditions and chemicals.

2.1.2.4 COIR

Coir though technically a natural fiber, coir is often treated with synthetic additives for enhanced performance. Used in erosion control blankets, weed barriers, and as a component in composite materials for agro-textiles.An erosion control blanket is composed of a woven
coir mat that protects seeds or seedlings from wind and rain and further facilitates growth, it also protects soil from erosion and mulching action. The basket liners of the coir provide better aeration for growth as air can flow more effectively through the holes of the coir pad. They also help in the vigorous growth of roots.[4]

Benefits: Naturally biodegradable but often enhanced with synthetic components to increase durability and performance.

2.1.3 MAN-MADE FIBERS

Man-made fibers, also known as synthetic fibers, are engineered from polymers and have a broad range of applications in agro-textiles due to their specific properties and performance characteristics. Here's an overview of some common man-made fibers and their uses in agro-industry. Man made fibers are

preferred for agriculture merchandise than the natural fibers, specifically because of their favorable charge ratio, ease of shipping, space-saving garage and long service existence as well as residences.[7]

2.1.3.1 POLYPROPYLENE

Weed Barriers: PP fabrics are widely used as weed control fabrics that block sunlight, preventing weed growth while allowing water and nutrients to pass through.This type of fabric is used to control the growth of weed. They are normally needle punched non woven fabric.[9]

Erosion Control Mats: Used for soil stabilization and preventing erosion in areas prone to soil loss.

Mulch Mats: PP is also used in mulch mats that retain soil moisture and regulate temperature.

Benefits: Lightweight, resistant to water and chemicals, durable, UV-resistant, and cost-effective.

2.1.3.2 POLYESTER (PET)

Soil Stabilization Fabrics: Used in geotextiles to reinforce soil structures and prevent soil movement.

Erosion Control Blankets: Helps stabilize soil and support vegetation growth in erosion-prone areas.

Crop Protection Netting: Provides protection from pests and harsh weather.

Benefits: Durable, strong, resistant to UV degradation and abrasion, maintains dimensional stability.

2.1.3.3 NYLON (POLYAMIDE)

High-Strength Ropes and Nets: Used for agricultural support structures, such as trellises and nets.

Soil Reinforcement: Used in geotextiles for soil stabilization and reinforcement.

Erosion Control: Used in high-strength erosion control fabrics.

Benefits: Extremely strong, elastic, resistant to wear and tear, good resistance to environmental conditions.

2.1.3.4 POLYETHYLENE (PE)

Mulch Films: Used to cover soil and crops to retain moisture, regulate temperature, and reduce weed growth.

Greenhouse Films: Provides protective covers for greenhouses, enhancing light transmission while protecting plants from external conditions.

Benefits: Flexible, durable, and resistant to water and UV rays.

2.1.3.5 VINYL (POLYVINYL CHLORIDE, PVC)

Protective Covers: Used for creating covers and protective sheets for crops and soil.

Water Management: Used in irrigation systems and water conveyance structures.

Benefits: Water-resistant, durable, and flexible.

2.2 AGRO TEXTILES: A DECADE OF INNOVATION (2015-2025)

The agro textiles industry has undergone significant transformations, driven by advancements in materials, sustainability practices, and smart technologies.

2.2.1 MATERIAL INNOVATIONS

Biodegradable Options: Jute, hemp, and other eco-friendly materials have gained prominence, replacing conventional synthetic fabrics.In recent decades, many studies have been conducted to develop and industrialize socalled biodegradable plastics that would not accumulate in the environment. An example is ox o-degradable plastic, which is essentially conventional plastic (e.g., PE, PP, PET) with additives (prodegradants) that accelerate the oxidation process.[10]

High-Performance Fibers: Advanced polymers and nanotechnology have created lightweight, durable fabrics resistant to UV radiation, pests, and harsh weather.

2.2.2 SUSTAINABILITY PRACTICES

The use of agro-textiles as complementary solutions for the implementation of a sustainable agriculture represents the scientific reaction to the challenges that determine the appearance and installation of the imbalance in an agro-system[5].

Reduced Chemical Use: Agro textiles minimize chemical inputs, with mulching films suppressing weeds without herbicides.

Water Conservation: Moisture-retentive materials support sustainable irrigation practices in water-scarce regions.

2.2.3 SMART TECHNOLOGY INTEGRATION

Io T-Enabled Textiles: Sensors monitor environmental conditions, enabling data-driven decisions.

Automated Systems: Smart agro textiles optimize resource use and enhance crop productivity.

2.2.4 DIVERSE APPLICATIONS

Horticulture : Shade nets, insect screens protect crops from stress and pests.

Aquaculture: Textiles improve water quality, provide habitats for aquatic life.

Soil Erosion Control: Geo-textiles stabilize soil, prevent erosion as well as for construction projects

2.2.5 MARKET DYNAMICS

Growth Trends: Robust growth driven by sustainable farming practices, higher productivity.

R&D Investments: Companies innovate, develop solutions addressing agricultural challenges.

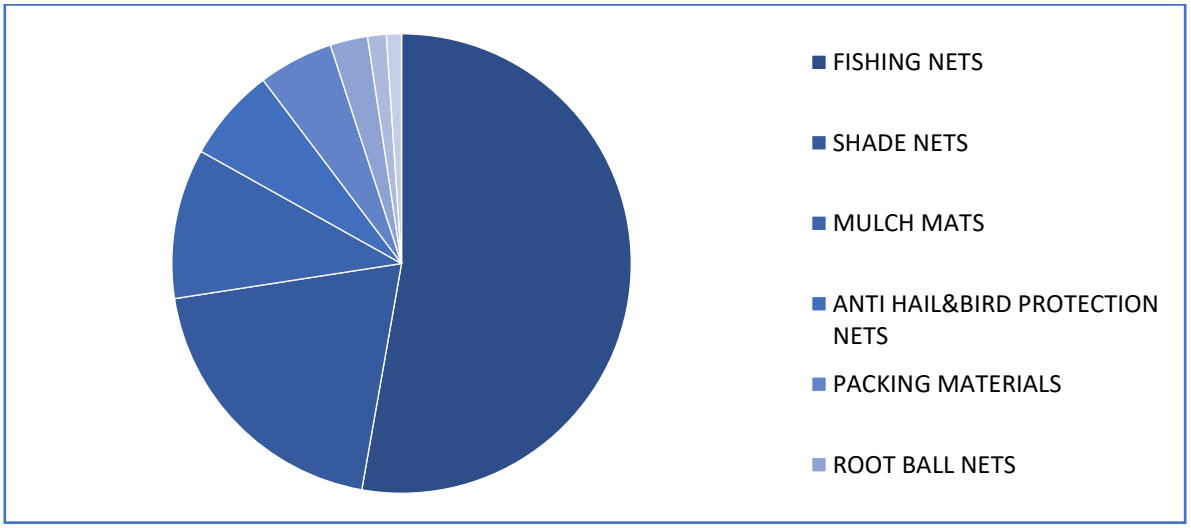
2.2.6 REGULATORY AND ENVIRONMENTAL CONSIDERATIONS

Regulations: Stricter chemical use regulations encourage agro textile adoption.

Environmental Impact: Companies prioritize life-cycle assessments, minimizing ecological footprint.

2.3 END-USE INSIGHTS

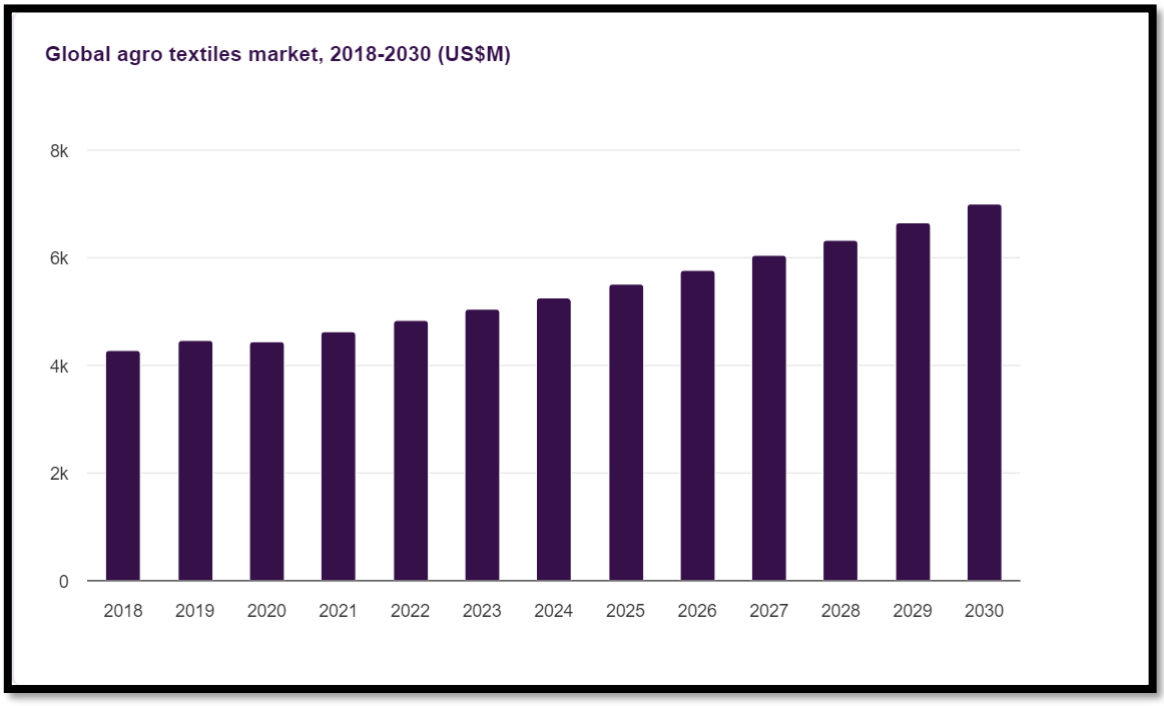
In 2021, fishing nets dominated the global market, representing over 54.00% of total revenue. The growing utilization of aquatic organisms across multiple sectors, including nutraceutical, pharmaceuticals, and cosmetics, coupled with an increase in seafood consumption, has significantly contributed to the expansion of aquaculture, thereby enhancing the growth of the fishing net segment. Shade nets are selected based on the specific crops cultivated beneath them, taking into account the light tolerance of each crop. Furthermore, these nets are instrumental in improving agricultural yields during the summer months and mitigating damage caused by excessive heat. They find applications in various fields, including arboriculture, nurseries, and vermicomposting.



Farmers highly favor mulch mats composed of natural fibers due to their biodegradability, which contributes to the replenishment of soil nutrients once the mats reach the end of their life cycle. This characteristic promotes sustainable farming practices and mitigates the adverse effects associated with the disposal of synthetic materials. In regions susceptible to hail, particularly in high-altitude and colder climates, anti-hail nets are employed. These nets are typically utilized for tall fruit trees in hail-prone areas, with each tree requiring its own protective net. Constructed from HDPE yarn, these nets are either woven or knitted and are treated with UV stabilization to endure the impact of falling hail.

2.4 GLOBAL AGRO TEXTILES MARKET HIGHLIGHTS

The global market for agro textiles achieved a revenue of USD 4,619.3 million in 2021 and is projected to grow to USD 6,978.5 million by 2030. The anticipated compound annual growth rate (CAGR) from 2022 to 2030 is 4.7%. In terms of market segments, synthetic fibers generated a revenue of USD 3,250.0 million in 2021. The natural fibers segment is expected to be the most profitable, exhibiting the highest growth rate during the forecast period. Regionally, the Asia Pacific emerged as the leading market in terms of revenue in 2021. Furthermore, the United States is forecasted to experience the highest CAGR from 2022 to 2030



CONCLUSION

The past decade has seen agro textiles evolve significantly, integrating advanced materials and smart technologies while prioritizing sustainability. As farmers seek efficient, eco-friendly solutions, agro textiles will play a vital role in achieving sustainable agricultural practices worldwide.

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