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Review on Windbreaks Agroforestry as a Climate Smart Agriculture Practices

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Abstract: Nowadays, climate variability and changes are among the main environmental challenge within the world. The negative implication of global climate change on the agricultural sector is unequivocal, as its consequences affect the livelihoods of particularly smallholder farmers within the tropics. Windbreaks agroforestry practices has been offered as a climate smart agriculture technologies or practices to reduce the global climate variability and climate change. It is one of the most important adaptation and mitigation strategies of climate change. This review paper focuses on the importance of windbreaks agroforestry practices in global climate change adaptation and mitigation, the role of windbreak technology at the farm and landscape levels, effects of windbreaks on reduction wind speed and soil protection, role of windbreaks to reduce the vulnerability of climate change. Windbreaks can improve the efficiency of ecological and ecosystem services provided by natural resource. If planned properly, nitrogen-fixing trees also can provide direct benefits for increasing the productivity of agricultural crops in an organic way and by resulting higher yields. They enhance animal health, feed efficiency, reduce smells, and increase producers' economic returns when utilized in livestock production systems. Windbreaks can help boost crop productivity, diversify goods, and lift farm revenue by improving soil quality and reducing erosion, improving water quality and reducing flooding damage, improving animal habitat and biodiversity, and lowering pest control inputs. Within the final section, the precise challenges to adapting windbreaks agroforestry practices and adoption mechanisms were reviewed. Windbreaks agroforestry systems may prove to be very useful component of agricultural adaptation as both an economically feasible adaptation strategy for smallholder farmers vulnerable to climate change as well as a profitable greenhouse gas mitigation opportunity.

Keywords: Adoption Mechanisms, Climate Change, Climate Smart Agriculture, Windbreaks Agroforestry

1. Introduction

Windbreaks are highly valued for delivering ecological benefits that reach well beyond the farm. Enhancement of biodiversity, wildlife habitat [1], carbon storage [2]. Agroforestry windbreaks, according to [3-5], provide wind protection, reduce evapotranspiration from croplands, reduce transpiration from plants, control-blowing snow, provide animal habitat, shelter for honeybees, energy savings, and aesthetic value. Windbreaks offers shade for livestock, visual screening, aesthetics, recreational possibilities, and wood and non-timber forest products (NTFPs) once they are employed for non-wind uses [6, 7].

The advantages of windbreaks are diverse, and their effectiveness is contingent the windbreak's intended function. When planned for wind decrease purposes, these systems can generate more favorable situations that enhance field and orchard crop production [8], reduce the spread of crop diseases like citrus canker [9], decrease honey bee death throughout the winter [10], enhance foraging of honey bees during times of wind [11], reduce risk of livestock mortality during winter storm cases [7], reduce destruction, increase water-use efficiency, reduce energy, heating charges.

As a result, adaptation to global climate change |temperature change in smallholder farming communities is anticipated to strengthen the role of windbreak agroforestry techniques in decreasing/reducing the impact of climate change and its repercussions. Adoption of agroforestry/windbreak methods, also as advancements in climate-smart agriculture, is anticipated to profit greatly. The target of this paper is to review the available literatures on enhancing the understanding of windbreak agroforestry practices.

2. Literature Review

2.1. Definition and Scope of Agroforestry and Windbreaks

2.1.1. Agroforestry

Agroforestry, defined as a planned combination of trees and crops on the same land with or without livestock, is quickly becoming recognized as a viable technique for balancing agricultural output and environmental protection [12, 13]. Agroforestry is an efficient land-use method for reducing erosion and maintaining soil fertility when paired with contour planting on sloping uplands [14].

2.1.2. Windbreaks

Windbreaks are one or more rows of closely spaced trees and/or bushes placed at right angles to the prevailing winds to shelter crops, soils, animals, and structures from the prevailing winds. Windbreaks might assist if wind is a problem in your region. Various authors' well-defined windbreaks as plantings of single or multiple rows of trees or shrubs that are established for one or more ecological purposes [3]. Windbreaks are trees or shrubs planted to scale back wind velocities and, as a result, reduce evapotranspiration and stop wind erosion; they often provide direct benefits to agricultural crops, leading to higher yields, and supply shelter to livestock, grazing lands, and farms, consistent with the [5].

Windbreaks are an agroforestry strategy that involves intentionally establishing linear plantings of trees and shrubs in an agricultural landscape to offer economic, environmental, and social advantages, which will arise when trees are maintained in an agro ecosystem. Windbreaks in agro environments are classed as field, livestock, or farmstead counting on their location and functional purpose, and specific design arrangements are referred to as hedgerows, shelterbelts, living snow fences, or vegetated environmental buffers.

2.2. How Windbreaks Agroforestry Practice Developed and Implemented

Windbreaks are often created by leaving existing trees in strips or by planting trees between fields, inside fields, and near farm buildings. Height, density, direction, length, width, continuity, and cross-sectional shape are the seven main factors to think about while creating a windbreak [15], and by combining trees, shrubs, and tall permanent or annual plants. Windbreaks are "environmental buffers" that are planted during a number of locations, including agriculture, pasture, and rangeland, roadways, farmsteads, feedlots, and in urban areas. Windbreak agroforestry practices that are properly designed and implemented can increase crop production, diversify products and farm income, improve soil quality and reduce erosion, improve water quality and reduce flooding damage, improve wildlife habitat and biodiversity, and reduce pest management inputs [16].

Windbreak's external and interior construction determines its capacity to perform its purpose within the terrain. Width, height, form, and orientation all determine the outward structure. The quantity and placement of branches, leaves, and tree or shrub trunks determine the inside structure [7]. Windbreak height on the to leeward has been observed to scale back wind speed by 20–35-fold counting on optical porosity [17].

2.3. Role of Windbreak Technology at the Farm and Landscape Levels

Windbreaks are used for a spread of purposes, including wind protection, reducing wind erosion, protecting growing plants, improving irrigation efficiency, controlling blowing and drifting snow, establishing wildlife habitat, energy conservation, living screens, odor abatement, and more. A system of whole-farm resource consumption balanced with whole-farm production is defined as sustainable agriculture [18]. In integrated agricultural systems, trees and shrubs play a big role. Riparian woods offer wildlife habitat and wood, protect river and stream banks from erosion, and performance as filter strips for agricultural runoff, so protection water quality and fish habitat.

2.3.1. Farmstead Windbreaks

Farmstead windbreaks safeguard the house site while also lowering energy use. Building protection for farms and ranches may be a reliable method to chop heating and cooling costs connected with these properties. Windbreaks lessen the consequences of wind chill on people, making outdoor labor less unpleasant, more efficient, and safer during the winter months. Windbreaks positioned properly decrease snowdrifts in roads and work areas, save on snow removal expenses, and increase the worth of the property. It going to give shade and provides a comfortable outdoor family play space during the summer, lowering air con expenditures.

2.3.2. Livestock Windbreaks

Windbreaks for livestock can reduce stress, boost weight gain, and minimize young animal mortality. Windbreaks provide several advantages to a successful livestock business. The idea, like with crops, is to use the microclimate conditions provided by shelter to enhance the animal production system. Livestock serves dual functions in sustainable agricultural systems. They transform grass, grain, agricultural waste, and other non-economic byproducts into high-value commodities like milk, eggs, and wool. They supply a crucial way for cycling nitrogen, minimizing the necessity for external inputs. Windbreaks built to guard

feedlots, pastures, or rangelands boost their output on an integrated farm operation. Livestock in protected environments have reduced cold temperature stress, better health, higher feeding efficiency, and better reproductive performance.

2.3.3. Field Windbreaks

Field windbreaks are considered to be a part of a sustainable agricultural system consisting of single or multiple lines of trees and shrubs planted along the sting of agriculture lands mainly to scale back the wind erosion and supply protection to field crops [7]. Windbreaks within the field diminish wind speed and alter the sector environment. Crop growth and development benefits vary counting on the crop, soil type, and native environment. Snowfall that is evenly distributed supplies moisture to the soil, which is useful to spring crops. Changes in temperature and humidity may reduce evaporation and boost crop water usage efficiency and photosynthetic efficiency. While windbreaks necessitate the removal of some cropland, they end in a net gain in total crop output and quality. Overall, there is an honest net economic return, lower input prices, and better environmental circumstances.

2.4. Effects of Windbreaks on Wind Speed Reduction and Soil Protection Against Wind Erosion

According to Kucera et al, [19] and Reháek et al [20] found that windbreaks could effectively protect against wind erosion, especially when agricultural plants do not cover the soil. Within the agricultural landscape, windbreaks and other linear constructions reduce wind speed and improve the microclimate within the sheltered zone. They need good sort of direct effects on agricultural productivity while also optimizing biodiversity benefits [21]. Windbreaks planted in citrus orchards have been found to reduce wind damage by up to two times the area of the windbreak height, lowering wind speeds by 80-95 percent [9]. Wind erosion is triggered by a spread of things, including wind speed, precipitation, surface roughness, soil texture and aggregation, agricultural activities, vegetation cover, and land block size [17], also as freezing and thawing cycles or freeze drying during the winter. Windbreaks reduce wind speed and strength, which is one among the strategies for permanently avoiding soil loss.

2.5. Environmental Benefits of Trees as Windbreaks

According to Alemu [22] Windbreaks that are well established and managed provide numerous benefits to the efficiency of ecological and ecosystem services provided by natural resource. When trees are utilized as windbreaks, they lower wind speeds and shelter crops and pastures from drying winds. Moreover, the author pointed out that windbreaks, as part of their ecological role, have led to a 25% rise in crop yields, a 20% increase in pasture yields, and a 10% increase in dairy milk output.

2.5.1. Agricultural Benefits of Windbreaks

According to Smith et al. [23], Windbreaks on agricultural areas are largely for indirect economic advantages (Soil erosion control, livestock protection, wind protection and snow control) and direct agricultural advantages (enhanced crop and livestock production) are followed by essential values (aesthetics and wildlife habitat). It provide efficient protection from severe winds on the to leeward by minimizing wind erosion, shielding crops from physical damage, regulating the impacts of snow, and increasing irrigation efficiency [4].

According to Richard and James [24], windbreaks with a density of 40% will provide adequate crop protection, while windbreaks with a density of 60% will effectively prevent wind erosion. Nitrogen-fixing trees also are thought to feature to the productivity and production of neighboring cropland in an organic sort of farming. Windbreaks that are well managed also will help to extend cattle productivity and output. Furthermore, forage and fodder trees could be used as a source of food for animals. For livestock production, windbreaks also act as odor screens [25].

2.5.2. Wildlife and Windbreaks

Windbreaks also will aid within the creation of a habitat for wild animals and birds by allowing them to readily get the essential wild animal habitat demands of food, cover, and space [26]. Well-established windbreaks can provide a habitat for wildlife breeding and nesting for birds and therefore the breeding of birds, which will feast on insects, which will emerge from cropland [27]. It will also provide a secure haven from predators and adverse weather for wild creatures.

2.6. Role of Windbreak Agroforestry Practices to Minimize the Vulnerability of Climate Change

Agroforestry systems, for example, can assist systems adapt to increasing climatic unpredictability while also mitigating greenhouse gas emissions through sequestration [31]. By improving production and financial stability, windbreak agroforestry systems provide many benefits for smallholder farmers vulnerable to the effects of climate change and may prove to be especially important in rural, agriculturally centered economies with few extra livelihood possibilities [8].

Windbreak agroforestry systems have been demonstrated to enhance on-farm production resilience to climatic variability by buffering crops from the effects of temperature and precipitation fluctuation, as well as high winds associated with storms, as a means of adapting agriculture to climate change [28]. According to Lin BB [29] Crops grown in heavy shade 60-80 percent of the time were kept 2-3°C cooler during the hottest times of the day than crops grown in light shade 10-30 percent of the time and lost 41 percent less water through soil evaporation and 32 percent less water through plant transpiration in coffee agroforestry systems.

Agroforestry systems also tend to have more crop diversity inside them, resulting in a wider variety of food, fuel, and fodder products being generated for smallholder farmers [30]. According to Verchot [31] Agroforestry systems that

reduce the outward flux of CO_2, N_2O, and CH_4 through better management will contribute significantly to reducing GHG emissions, and mitigation studies have identified agroforestry systems as a potential long term GHG sink.

Agroforestry systems have a carbon sequestration capacity of between 12 and 228 Mg C ha^{-1}, with a median value of 95 Mg C ha^{-1} [32]. For smallholder agroforestry in the tropics, potential carbon sequestration rates range from 1.5-3.5 Mg C ha^{-1} yr^{-1} [33]. Farmers may be able to supplement their revenue by selling carbon credits, further diversifying their agricultural portfolio. Carbon sequestration in agroforestry systems has the potential to increase per capita earnings of farmers by up to 15% at prices of $100 per Mg C, according to policy research [34]. Significantly, windbreak agroforestry systems is a valuable component of agricultural adaptation, serving as an carefully viable adaptation method for smallholder farmers who are sensitive to climate change as well as a cost-effective greenhouse gas mitigation possible.

2.7. Adoption Mechanisms of Windbreaks Agroforestry Practices to Climate Change

Agroforestry has huge potential to adapt and mitigate climate change. It provides a unique opportunity to reconcile the objectives of mitigation and adaptation to climate change [35]. As adaptation emerges as a science, the role of agroforestry in reducing the vulnerability of agricultural systems to climate change or climate variability needs to be addressed [36]. Microclimate improvement through increased moisture and reduced warmth, shading impact reduces evapotranspiration from crops, high biodiversity, which reduces pest and disease incidence, and buffering agricultural crops against water shortages are some of the adaptive strategies of agroforestry.

2.8. Main Challenges to Windbreak Agroforestry Practices

According to Thomas [37], agroforestry programs must overcome significant social, economic, and environmental constraints in order to succeed. According to Nath et al. [38], lack of knowledge about planning and management techniques, choice and domestication of potential tree species, management guidelines, lack of attention given to tree products and services in information assortment, policy constraints, and marketing are some of the technical obstacles that limit the rapid expansion of agroforestry. The basic constraints affecting the windbreaks agroforestry practices are as follow. These are -

2.8.1. Unsecure Land Tenure System

Ambiguous land tenure, lack of land use management is common in developing countries, leads to confusion regarding land delineation and rights. If people do not have title to land, there is a perception that there is no point in finance in trees, which may take a long time for benefits to be accomplished. It is expected that farmers that feel secured (sure to inherit land they cultivate to their descendants) build the choice to take a position in future investment [39, 40].

2.8.2. Labor Requirements

Family members often do cultivation, and labor shortages are commonly mentioned as a reason why agroforestry technologies are not extensively used [41]. Moreover, rural individuals scrutinize labor necessities before they decide whether or not or to not adopt replacement agroforestry follow [42]. Though the additional labor costs will be compensated by additional benefits, the immediate need for additional labor may be a deterrent to expanding agroforestry practices [41].

2.8.3. Lack of Available Marketability of Products

The information has indicated that access to markets and raw materials and structure and management skills are among the main constraints to the expansion of those enterprises [43]. Another constraint in delivering tree product to markets for several tree product, markets are poorly structured and coordinated [44, 41].

2.8.4. Short-Term Thinking

Unimproved access to markets might encourage farmers to follow unsustainable land management for gaining short profits. The lack of knowledge in tree seed plant management; pest and disease control; adequate seeds and germplasm provide is another constraint to agroforestry follow [42]. Furthermore, there is a lack of knowledge among farmers about the environmental advantages of trees, as well as misconceptions about trees, such as the fear of trees shading crops and fruit trees [39].

2.8.5. Lack of Resources

Farmers are less likely to worry about soil fertility using manure on distant farm lots and a lot of seemingly to use slash-and-burn for land preparation, which ends up in improved nutrient loss and erosion [41]. Inadequate access to capital and credit is usually considered as a serious constraint for increasing household production and financial gain to invest in additional economical land use.

3. Conclusion

Windbreaks are “environmental buffers” planted in a variety of places, including farmland, pasture, and rangeland, highways, farmsteads, feedlots, and urban areas. It may be produced by planting trees between fields, inside fields, and near farm buildings, as well as mixing trees, shrubs, and tall permanent or annual plants. Different species can directly contribute to the production of nuts, fruits, lumber, and other wood products when they are integrated in the design. The seven essential elements to consider while designing a windbreak are height, density, direction, length, breadth, continuity, and cross-sectional form.

In the context of agroforestry practices, windbreaks are a major component of successful agricultural systems. Well-established and managed windbreaks provide manifold benefits the efficiency of ecological and ecosystem services of land resources. Windbreaks can enhance crop outputs, diversify products and farm income, increase soil quality and

decrease erosion, recover water quality and reduce flooding damage, improve wildlife habitat and biodiversity, and reduce pest management inputs. Windbreaks provide protection from the wind, reduce evapotranspiration from croplands, reduce transpiration from plants, control-blowing snow, provide habitat for wildlife, shelter for honeybees, energy savings, and aesthetic value. When used in livestock production systems, they improve animal health, improve feed efficiency, mitigate odors, and contribute to the economic return for producers.

Windbreaks that are properly built can provide extra revenue from wood products, tree crops, and fuel wood. Windbreaks have potential to assist with adapting to future changes in climate and may, in some cases, ease the economic burdens associated with change. Windbreaks agroforestry systems may demonstrate to be very useful fundamental of agricultural adaptation strategy for smallholder farmers exposed to climate change as well as a gainful greenhouse gas mitigation opportunity. The integration of managed agroforestry systems, tree shelterbelt, and windbreaks into climate smart agriculture can moderate the effects of climate changes to a certain extent and improve the agricultural production.

Finally, windbreaks enhance the environment's beauty while also increasing land value and enhancing soil fertility. Many sorts of farms, including animal farms and crop fields, benefit from windbreak agroforestry techniques. By minimizing wind and water erosion, it benefits environmental sustainability as well as agricultural production and productivity.

4. Recommendations

Based on the reviewed articles of different literatures, the following recommended as follows:

1) Windbreaks agroforestry practices and systems comprise various models in several regions worldwide, that plays a fascinating role to regulate the negative impact of global climate change and soil degradation by increasing tree-crop diversification that leads to a lot of carbon storage and rehabilitation of degraded soil capability than alone cultivation of solitary crops. So, the use of trees as windbreaks and shelterbelts needs to be encouraged by policy and strategy makers.
2) Because windbreaks agroforestry benefits agricultural production in many ways, so all farmers and agricultural scientists, research and demonstrations will be necessary to obtain and disseminate information about benefits and utilization of windbreaks and their products.
3) The combination of succeeded windbreaks agroforestry systems as a climate smart agriculture practices can alleviate the effects of climate changes to a certain extent and intensification of agricultural production. Therefore, policymakers and other relevant stakeholders should give great attention to strength windbreaks agroforestry practices as climate change adaption and mitigation.

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