Environment Pollution and Climate Change

Gemeda and Wariyo, Environ Pollut Climate Change 2023, 7:5

Research Article Open Access

The Role of Agroforestry Lowering Farmers' Exposure to Climate Change

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Abstract

Agroforestry plays a crucial role in climate change adaptation and increases resilience to its effects by promoting diverse land-use patterns, sustainable livelihoods and income streams, higher forest and agricultural output, and a reduction in production losses due to weather. Agroforestry has had a significant role in reducing farmers' sensitivity to shock. Reduced susceptibility, improved farming system resilience, and home protection from climate-related dangers are all made possible by trees. Subsistence farmers are among those who are most sensitive to current climatic fluctuation. For smallholder farmers who are susceptible to the effects of climate change, agroforestry systems offer a number of benefits. These systems may be particularly crucial in rural, agriculturally based economies where there are few other viable sources of income. They can also boost output and financial stability while assisting systems in adjusting to increased climatic variability and mitigating greenhouse gas emissions through sequestration. Increased agricultural production, environmental sustainability, food security, income diversification, specific coping mechanisms, a higher standard of living, and soil and water conservation are some of the major advantages of agroforestry. Many agroforestry systems have the capacity to both lessen and respond to climatic uncertainty. Agroforestry systems, in general, voluntarily include both mitigation and adaptation techniques and provide disadvantaged farmers with a variety of options to guarantee food security while minimizing climate change.

Keywords: Agroforestry; Climate change; Vulnerability; Resilience; Farmers

Introduction

Climate unpredictability is a reality that presents difficulties for everyone. It is seen as a change in weather patterns in some regions while becoming a question of survival in others. The latter is especially true in underdeveloped countries where the majority of people depend on agriculture supported by rainfall for a living. Although many people's livelihoods depend on agriculture, it is the one that is most at risk from the effects of climate change. Due of this, communities that depend on it may be exposed to climate change. As that agriculture is rain-fed, one of the main solutions is to take agricultural or land-use measures that could lessen or accommodate the risks associated with climate change [1].

Due to the substantial effects that climate change is having on natural and human systems across all continents, food production is declining and there is an increase in food insecurity in many regions of the world. According to Nelson (2009), a 10–20 percent reduction in agricultural production is possible over the course of the next 40 years, which will have a significant impact on rural people in developing and transitional countries. To decrease the predicted effects of climate change and the vulnerability of the poor to it, solutions are being developed.

Agroforestry is frequently suggested as a solution to the problems of both food security and climate change. When there are two or more crop seasons in a row, agroforestry practices like planting leguminous trees during the fallow period are used (improved fallow). By integrating short- and long-term trees with crops (distributed intercropping), agroforestry can also increase resilience to climatic variability, lessen the effects of extreme weather events like droughts or heavy rain, and promote well-being in many tropical places. Agroforestry contributes to slowing climate change while this is happening by expanding and developing carbon sinks, which are regions where carbon dioxide from the atmosphere is absorbed and stored in things like biomass and soil [2, 3].

It is important to consider this from the farmers' perspective because local biophysical and socioeconomic factors greatly determine how much agroforestry practices contribute to enhancing farmers' livelihoods. Despite the worldwide advantage of regulating climate through carbon sequestration, smallholder farmers need to invest in innovative farming practices as well as bettering their livelihoods and changing their lives. As a result, mitigation efforts at the level of smallholder farms must directly and concretely support farmers' livelihoods, for as by giving them access to food, fuel, or fodder, with mitigation working as a by-product of the improved agricultural practice. According to numerous studies, the only factors that are measured are agroforestry's essential role in boosting resilience to climate-related hazards or the amount of carbon storage in smallholder systems. In light of this, the goal of this study is to examine how agroforestry makes farmers less susceptible to climate change.

Methodology

Concept and definitions key terms

Vulnerability: Vulnerability is the measure of a system's susceptibility to or incapacity to handle the harsh environment brought on by climate change, particularly its unpredictable nature and past extreme occurrences. The degree of vulnerability of a system depends on its susceptibility to climatic variability, the type, degree, and pace of climatic dissimilarity to which it is strongly exposed, as well as its capacity for survival. Resilience must be increased while exposure and

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Received: 03-August-2023, Manuscript No. EPCC-23-108372; **Editor assigned:** 05-August-2023, Pre QC No. EPCC-23-108372 (PQ); **Reviewed:** 19-August-2023, QC: EPCC-23-108372; **Revised:** 22-August-2023, Manuscript No. EPCC-23-108372 (R); **Published:** 29-August-2023, DOI: 10.4172/2573-458X.1000349

Citation: Gemeda WK (2023) The Role of Agroforestry Lowering Farmers' Exposure to Climate Change. Environ Pollut Climate Change 7: 349.

sensitivity must be reduced in order to reduce a system's susceptibility to dangers associated with the climate [4].

Vulnerability is one of the traits of social and environmental processes. It is directly tied to the exposed system's susceptibility, sensitivity, and lack of resilience or capacity for adaptation to both extreme and non-extreme situations in the context of climate variability. It is described as being condition-specific and working in conjunction with a dangerous event to increase risk. Fundamental environmental components change continuity from the standpoint of climate change, which in turn creates new danger situations for societies. For example, more severe and frequent occurrences may disseminate risk elements to new areas, revealing core susceptibility. In fact, future vulnerability is already present in the current circumstances of the societies that may be exposed to future climate variability; as a result, underlying vulnerability factors will be exposed rather than necessarily created as new risks arise in previously unaffected areas [5].

(Figure 1)

Well-being: Human well-being is defined as "a state of being with others, where human needs are met, where one can act meaningfully to pursue one's goals, and where one enjoys and appreciates a satisfactory quality of life" by a three-dimensional holistic theory. This idea holds that in addition to material or financial well-being, happiness also encompasses relational and subjective well-being. Also, a number of scholars distinguish between the factors that determine wellbeing and their constituents. Examples of "determinants" are things that lead to or help make improvements in wellbeing while "constituents" are things like happiness, health, and positive interpersonal relationships. A few determinants are the accessibility of capital, expertise, and clean.

(Figure 2)

Climate variability: Due to climatic variability, numerous regions of the world have experienced and will continue to suffer various effects. The annual variance in the climate above or below a long-term average value is known as climate variability. Climate variability refers to climatic fluctuations that occur over seasons or years, as opposed to everyday circumstances, like when one rainy season is more intense or lengthy than others. Throughout the past century, mean surface temperatures and precipitation in the tropics have changed less than the global average.

The majority of the humid and sub-humid tropics may see an increase in the frequency of droughts, floods, and extreme rainfall events, which typically suggests greater precipitation variability, according to IPCC climate change predictions. Climate change will have a disproportionately negative impact on developing countries that still predominantly rely on rain-fed agriculture and other ecological resources. Moreover, due to human activity, rural regions are now more vulnerable to drought as population.

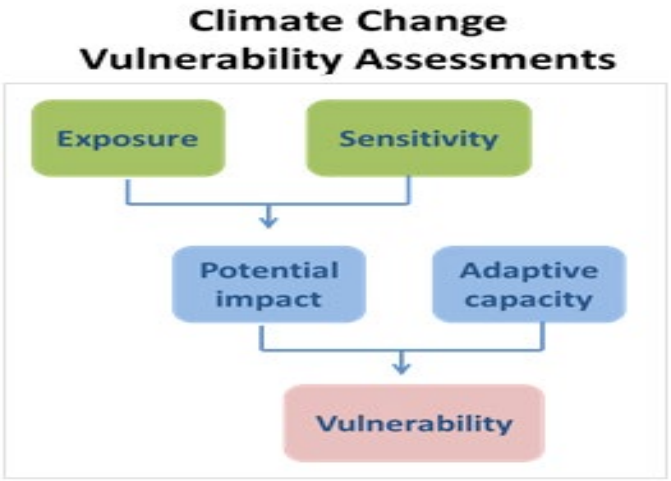

Figure 1: Vulnerability framework.

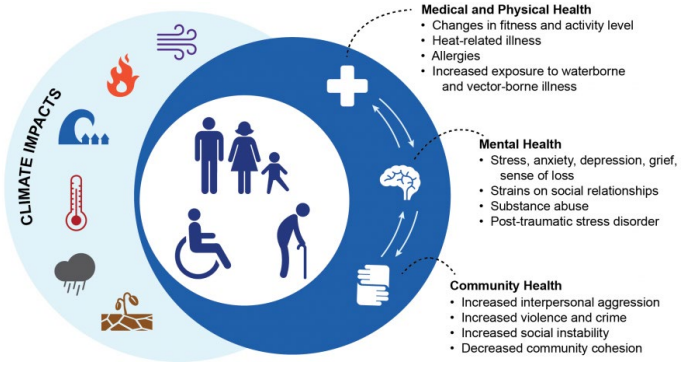

Figure 2: Human well-being diagram.

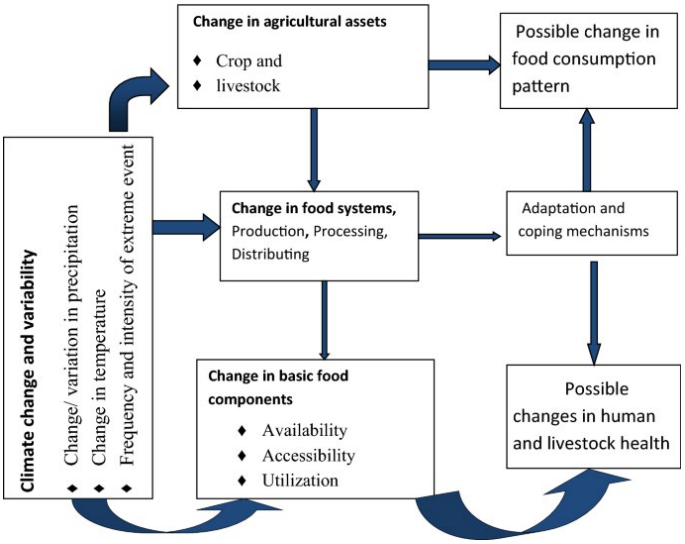

Figure 3: Diagram of climate variability.

(Figure 3)

Impact of climate change on farmers' well-being

Several research show that adverse effects of climate change on farmers' welfare. Rainfall variability can result in either floods or droughts, depending on the kind of deviation from the long-term normal. The management of natural resources, water resources, settlements, infrastructure, and food security are all impacted by variations in rainfall. Farmers that depend on seasonal cues to plant their crops struggle because of the more unpredictable weather patterns. Planting delays brought on by a decrease in rainfall have a big impact on agricultural output. When rain arrives earlier than expected, some crops are severely harmed. Farmers sometimes blame unpredictable rainfall that falls late in the growing season for crop illnesses like blight, which lowers their anticipated seasonal income [6-8].

Droughts have serious negative effects on the economy and society, especially in developing nations where a considerable amount of the national GDP is derived from agricultural production. Three

different types of consequences were discovered, including animal loss, decreased productivity, and higher production costs. People's wellbeing is directly impacted by these losses, especially in rural communities where livestock is the main source of income. Also, as a result of increased charcoal production, agricultural expansion, logging, and forest grazing during dry seasons, demand for natural resources, especially forests, increases during droughts.

Floods are more frequent than droughts and variations in rainfall, and they immediately impact human well-being. Communities are impacted by floods both immediately and later. Some of the immediate repercussions include loss of livestock and human life, increased disease risk, limited mobility, higher pricing for commodities, contaminated water, and difficulty locating cooking supplies, house damage, and increased food insecurity. Many long-term effects of floods include decreased soil fertility, loss of infrastructure and houses, emigration, and lower value of agricultural land. Throughout the past century, damage associated with floods has also grown due to increased land use, loss of forest cover, human encroachment on floodplains, and higher population concentrations in flood-prone areas.

(Figure 4)

Agroforestry systems

Agroforestry is the practice of purposefully integrating woody vegetation (trees or shrubs) with agricultural and/or animal production systems to benefit from the ensuing ecological and economic interactions. Common Agricultural Policy (CAP) and other state programs have frequently sped up the transition to specialized forms of agriculture and forestry. There may be an opportunity for an agroforestry renaissance as a result of the need to balance productivity and environmental improvement. Agroforestry can occasionally boost land productivity when the integration of tree and crop systems results in a more effective capture of resources (such as solar radiation or water) than separated tree or crop systems. Agroforestry has also been found to assist in managing ecosystem services including nitrogen cycling [9].

(Figure 5)

Agroforestry and vulnerability

Agroforestry has been proposed as a feasible tactic to assist subsistence farmers lower their vulnerability to climate change, according to. Sub-Saharan Africa has a great potential to sequester carbon and reduce other agriculture-related GHG emissions because 15% of farms there have at least 30% forest cover. Agroforestry systems can include crop diversification, long rotation methods for conserving soil, home gardens, bordering plantings, perennial crops, hedgerow intercropping, living fences, improved fallows, or mixed stratum

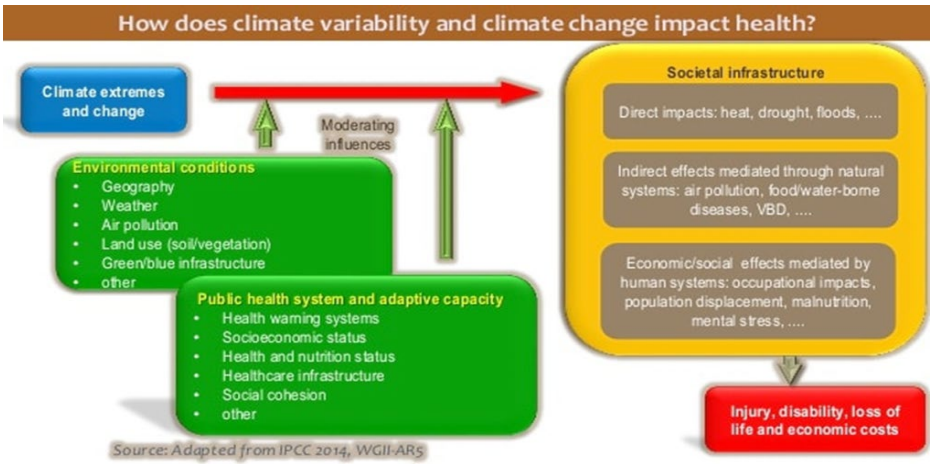

Figure 4: Impact climate variability and climate change on human health.

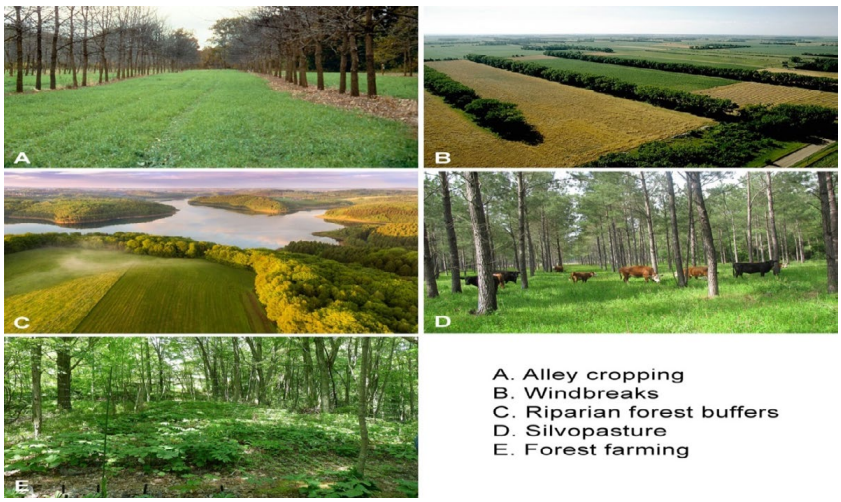

Figure 5: Agroforestry system.

agroforestry. Well-managed agroforestry can play a significant role in enhancing resistance to ambiguous climatic variability through microclimate buffering and water flow process management

Trees are believed to be less susceptible to climate-related risks like floods and droughts because they have deep root systems. A system's sensitivity is determined by the characteristics of the human-environment system, which includes the human, social, physical, and natural capital. By, for example, lowering sources of pollution like dust, limiting soil erosion, and creating habitats for wildlife, agroforestry helps to preserve and maintain natural resources. By concurrently conserving or replenishing soil and water supplies, it expedites flexible responses to rapid changes in ecological circumstances.

Development of agroforestry practices for sustainable fuel wood can assist replace energy sources and become a crucial component of solving the carbon balance problem. The use of agroforestry greatly reduces the time and effort required to gather fuel wood. Agroforestry improves agricultural productivity, off-farm revenues, wealth, and the environmental conditions of the farm to better a family's overall standard of living. Trees are another tangible resource used on the farm for protection and to increase the property's worth [10].

The ultimate results of agroforestry directly boost resilience. The results, such as the attainment of rights or an improvement in wellbeing, are a good gauge of resilience. These outcomes can be evaluated by looking at variables including food security, asset ownership, school attendance, nutrition, and other variables. The presence of trees on the farm serves as the best asset insurance and a plan for dealing with potential climate change situations. A direct source of food and fruits is agroforestry. Also, it provides an additional source of revenue from the sale of lumber and firewood.

Agroforestry's role in reducing climate vulnerability

Enhancing the wellbeing of farmers: Due of its dual function in helping farmers adjust to these changes and combating climate change through carbon sequestration, agroforestry practices have recently attracted increased attention. Agroforestry has been proposed as a potential strategy to help subsistence farmers minimize their susceptibility to climate change. Trees are intentionally used in agricultural systems to increase farm production, diversify income sources, and provide environmental services.

One strategy to boost farm productivity is to intercrop nitrogen-fixing trees between rows of food crops. This method does this by providing crops with nutrient availability in limited amounts. In agroforestry activities, tree products including fruit, wood, and fuel wood are also used and sold. Trees are believed to be less susceptible to climate-related shocks like floods and droughts because they have deep root systems. Agroforestry meets about half of the demand for both home and commercial wood. For instance, they offer around 80% of the required fire wood, 70% to 80% of the required wood to produce plywood, 60% of the required raw materials to produce paper pulp, and 9-11% of the required green fodder for cattle [11].

Carbon sequestration potentials of agroforestry

Carbon is extracted from the atmosphere by biological or physical processes and stored in a number of carbon sinks, including vegetation, soils, and seas. Carbon sequestration in the terrestrial ecosystem is facilitated by the biomass of both above- and below-ground plants, as well as the relatively stable forms of organic and inorganic carbon in the soil profile. Agroforestry practices could increase soil carbon stocks on agricultural lands, thereby supporting farmers in putting climate change mitigation policies into action and improving soil health. Agroforestry is an important prospective strategy for lowering atmospheric CO2, according to the Kyoto Protocol. In order to raise soil and above-ground carbon stocks globally and lessen greenhouse gas emissions and the effects of climate change, agroforestry systems seem to be a potential agricultural management method.

A considerable increase in the area covered by agroforestry will have a significant impact on the flow and long-term carbon storage in the terrestrial biosphere. Agroforestry systems store far more carbon than monoculture agricultural lands because they include more than two species, such as pasture [12].

(Figure 6)

Improve farmer livelihood

When evaluating the benefits of agroforestry to farmers' lives, which are influenced by local biophysical and socioeconomic factors, it is important to reflect their viewpoints. The possibility of carbon sequestration to influence climate on a global scale is not a strong justification for farmers to use new farming practices. As a result, smallholder farm mitigation operations are essential to generate direct benefits to farmers' livelihoods, such as providing food, fuel, or fodder, with mitigation being a co-benefit of higher agricultural output. The ability of farmers to adjust their way of life to the effects of climate change may be improved by agroforestry. Trees play a significant role in preventing climate change in addition to limiting exposure to threats associated to the climate.

Trees on farms significantly improve farmers' capacity to respond to the risks of climate change through crop and income diversification, soil and water conservation, and efficient nutrient cycling. AF products can considerably boost the economic development of the millions of poor farmers by meeting their needs for food, fuel, and income provided they are supported by efficient cultivation, processing, and marketing procedures.

Production diversification

Agroforestry generally boosts and diversifies agricultural productivity per area of trees, crops, and livestock, protects against negative effects of wind or water flow, and creates new products that increase the farming operation's financial flexibility and diversity. Also, it can significantly minimize the effects of climate change. Agroforestry systems, a conventional resource management adaptation, may

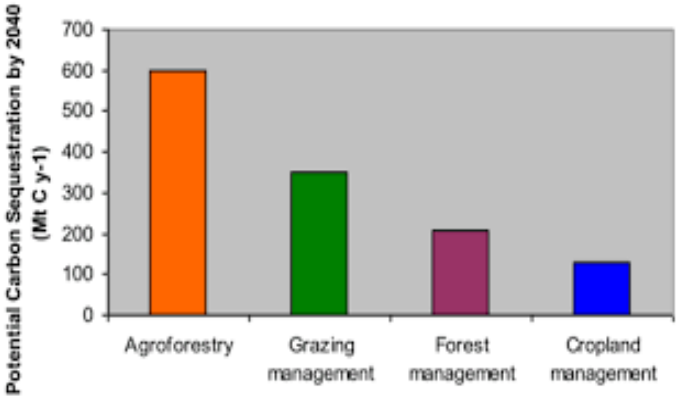

Figure 6: Potential carbon sequestration.

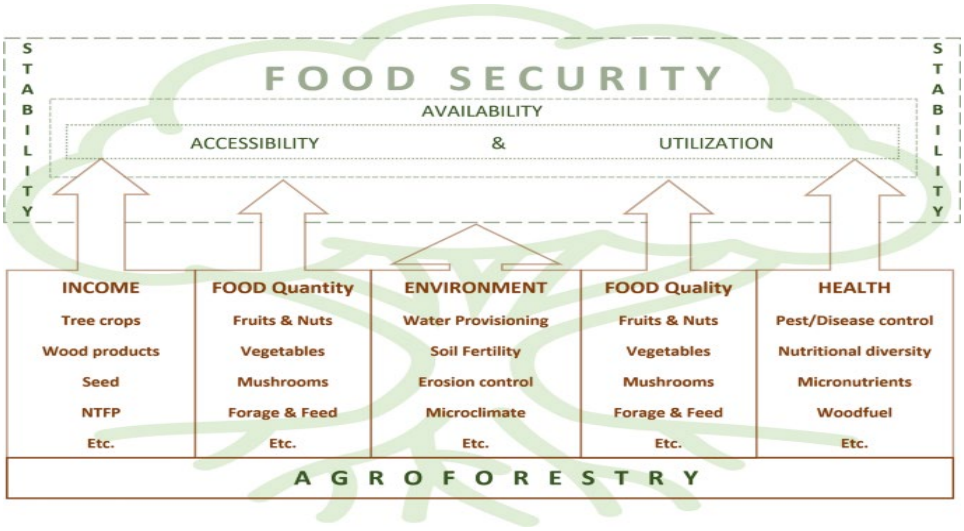

Figure 7: Diagram of addressing food security.

present prospects for enhancing farmer adaptation to climate change due to their direct provision of food, fodder, and firewood as well as minimizing the effects of climate change. The ability to diversify production, strengthen the resilience of subsistence farmers, and reduce production risk may be achievable as a result of the favorable correlations between agroforestry and adaptation to climate change.

Ecosystem protection

Agroforestry techniques that are sustainable have the potential to safeguard ecosystems and human livelihoods while laying the groundwork for long-term economic and social development. In particular under the current climate change scenarios, agroforestry systems support food security for farmers by supplying ecosystem services and diversifying agricultural yield. According to Verchot, planting trees alongside crops improves soil fertility, prevents and controls erosion, reduces water logging, avoids the acidification and eutrophication of streams and rivers, boosts local biodiversity, reduces the need for fuel from natural forests, and provides livestock with fodder. Also, it might strengthen the system's defenses against climate change's unfavorable effects.

Addressing food security

Agroforestry may be advantageous to farmers in a number of ways. By generating more commodities for sale or domestic consumption, it can frequently increase soil fertility and farm household resilience. The most crucial technologies for guaranteeing food security are agroforestry ones since they assist many people in escaping poverty and combating falling resource and agricultural production. For instance, the yields of crops on more degraded fields can be doubled or tripled when fertilizer trees are mixed with inorganic fertilizers. Furthermore, fodder trees can be utilized in smallholder zero-grazing systems to augment or replace commercial feeds, enhance kinds of temperate and tropical fruits that can be consumed to increase household income and nutrition, and grow swiftly into fast-growing timber and fuel [13].

(Figure 7)

Conclusion

Agroforestry has the potential to dramatically increase food security, resiliency to climate change, and the conservation of environmental resources. As a result, households are now much less likely to experience shock. With AF, one of the finest ways to help kids get past their risk aversion and out of food insecurity. Agroforestry is one of the most promising components, particularly as it relates to rural, smallholder farmers who have to adjust to more challenging climatological conditions including longer droughts, more severe floods, and more variable rainfall. It has been proposed as a possible tactic to lessen sensitivity to climate change and to produce resources and income from carbon, wood energy, enhanced soil fertility, and improved local climate conditions, as well as ecosystem services.

It is a flexible, ecologically conscious approach to resource management that incorporates farmland trees. Farm trees are used for regulation, preservation, and production. A landscape approach promotes collaboration between mitigation and adaptation, with carbon sequestration serving as a crucial technique for reducing climate change. The adverse effects of climate variability include food insecurity caused by droughts and floods, disease outbreaks like malaria and dengue fever, water-borne illnesses (like cholera and dysentery) linked to floods, respiratory illnesses linked to droughts, land degradation brought on by heavy rainfall, and damage to communication, roads, and other infrastructure caused by floods. These are just a few examples. Agroforestry systems provide numerous ways for struggling farmers to ensure food security and readily combine mitigation and adaptation techniques. They also help to reduce greenhouse gas emissions.

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