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## Landscape Diversity Enhances Climate Change Resilience: A Review

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**Abstract:** The review aimed at understanding landscape diversity in the face of global population pressure, agricultural land shortages, food insecurity, and climate insecurity. We used published literature to determine whether landscape diversity improves resilience to climate change. Literature searches were performed using the Science Direct database, Google Scholar search engine, and the professional network ResearchGate using keywords. Land degradation, soil resilience, and natural resources from 2000 to 2019. 120 publications were searched, including journal articles, reports, and book chapters. Of these, 68 were considered more relevant and all were read and considered in writing this review. Climate change, food insecurity, and land degradation have been established to be major challenges for developing countries leading to the loss of genetic diversity. Our results show that the loss of proper habitat may allow fast-growing invaders to occupy the remaining limited resources. Therefore, alien species may accelerate invasion under human-induced land-use changes during times of global change. The time lag between range expansion and habitat loss has been thwarted. A golden window to prevent the spread of alien species established in the habitat.

**Keywords:** Landscape Diversity, Biodiversity, Climate Change Resilience, Land Degradation

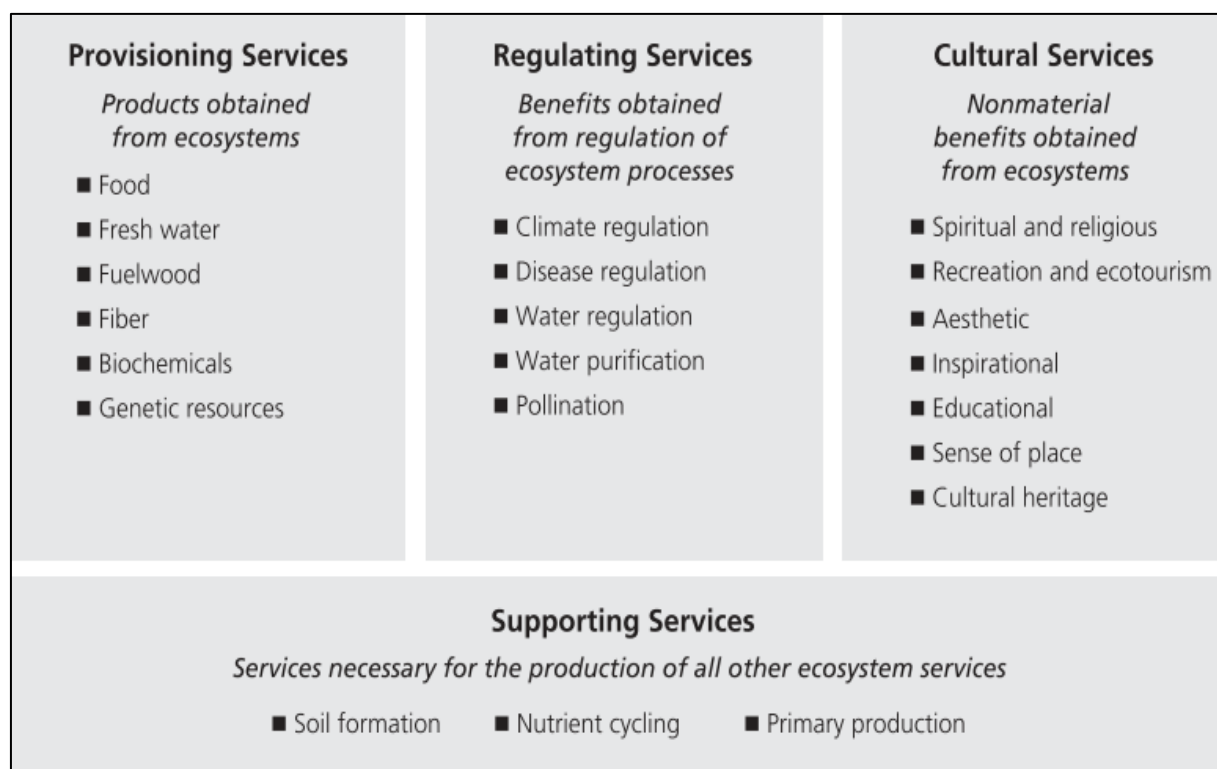
### 1. Introduction

The worlds' population is projected to reach 10 billion by 2100 thus requiring sufficient resources for their survival [1]. Food production need to increase to meet the food and fiber demands for the fast-growing population amidst climate uncertainties. Consequently, agricultural activities to produce more food to feed the populations have resulted into land degradation and loss of many species cross the glob [2-4]. Involvement of all stakeholders and good governance can provide a conducive atmosphere for landscape diversity strategic planning for sustainable development. Networking and research are key components of landscape diversity implementation strategy and require funds from both governments and donor agencies [5-10].

Landscape degradation in the 21st century is a related issue affecting climate change and food security in most developing countries. According to [11], a landscape is "a socio-ecological system consisting of a mosaic of natural and/or human-modified ecosystems, with characteristic configurations of settlements that influence topography, vegetation, land use, and ecosystems. The territory's historical, economic and

cultural processes and activities. The combination of land cover and land use type (landscape composition) usually includes agricultural land, native vegetation, human settlements, villages and/or or urban areas. The spatial arrangement of different land uses and cover types (landscape structures), and the norms and modalities of their management contribute to the character of the landscape." Based on this definition, landscapes can be seen from the lens of all ecosystems and the services they provide to humans. This includes, but is not limited to, agroecosystems, forest ecosystems, grassland ecosystems, and aquatic ecosystems. The landscape is the backbone of all ecosystem services, including supply, regulation and cultural services. [12] Humans play a central role in the maintenance and deterioration of landscapes due to human activities associated with population explosions [13-15].

With proper landscape management, we can always provide all the services we need, in the quantity and size we need, for the benefit of our people and the environment. Landscape destruction, on the other hand, undermines the ability to provide all necessary ecosystem services and harms humanity [4-6].



**Figure 1.** Categories of ecosystem services from the landscape (Source: [16])

Figure 1 shows the main categories and subcategories of ecosystem services derived from landscapes. Simply put, landscape is "our life" and we need our care and support for health and longevity. However, the provision of ecosystem services is undermined by climate change and land degradation.

Landscape degradation is intensifying as the population grows and demands more land to support livelihoods, primarily through agricultural activities. The United Nations (UN) predicts that it will reach 7 billion by the end of 2011, exceed 9 billion by 2050, and exceed 10 billion by 2100 [17]. In sub-Saharan Africa (SSA) alone, the elderly population is expected to increase from 46 million in 2015 to 161 million in 2050 [18]. In most developing countries, rainfed agriculture is the basis of people's livelihoods and requires more land for crop production. As a result, wetlands, natural forests, forest reserves, forests, and other natural landscapes are severely degraded at the expense of crop production to feed an increasing population [8-11]. To make matters worse, landscape homogeneity is practiced in both developed and developing countries, posing major challenges to biodiversity, human well-being and landscape resilience. Landscape resilience is described as "the ability of a system (in this case, a landscape) to maintain its balance in the face of the effects or stresses of natural or artificial interactions or events." Resilience systems (such as landscapes) have the ability to absorb disturbances and maintain essentially the same functionality, structure, and feedback. Resilience thinking is often applied to social ecosystems where

humans and the environment are connected [19]." The link between landscape management and its resilience is not well documented and should be reviewed. This review aims to examine published literature on how increased landscape diversity is important for their resilience and the continued provision of ecosystem services. This review covers the global perspective of nature's services from different landscape types around the world

## 2. Methodology

Literature search was performed using the ScienceDirect database, Google Scholar search engine, and the expert network ResearchGate with the following keywords: Land degradation, soil resilience and ecosystem services from 2000 to 2019. 120 publications were searched, including journal articles, reports, and book chapters. Of these, 68 were considered more relevant and all were reviewed and considered in writing this manuscript. Supplementary information contains output of the search results for this survey.

## 3. Justifying Landscape Diversification

Landscape diversification is the key to ecosystem stability and resilience. In a diverse landscape, there are all the necessary interactions between plants and animals. Healthy soil supports a healthy environment, which supports sustainable agriculture and, as a result, a healthy population [10-14].

This phenomenon can be achieved when the landscape is diversified to support different ecosystems in a particular area (Figure 2).

A diversified landscape will provide both a conducive habitat and feed for plants, microorganisms, animals as well as human beings. It supports conservation of nature, mitigates impact of climate change through carbon sequestration and enhance food security for human beings [20-22]. Landscape diversification is essential for social, economic and ecological reasons for the good of nature and man [5-19] [21]. It contributes to 5/17 United Nations 2030 sustainable development goals Table 1.

Goal 1: Due to the potential of agricultural landscape to increase crop production and farmers' income, agricultural diversity has potential to reduces households' poverty levels for the agriculture-dependent communities, especially in developing countries.

Goal 2: Increased soil health, environmental quality and agricultural sustainability improves crop production, avails essential nutrients to households and reduces malnutrition from populations of all age groups and gender.

Goal 6: Conservation of soil and water are the major outcomes of landscape diversity approach and this contributes to water availability for all the populations across the globe.

Goal 13: Landscape diversity addresses climate change impacts by reducing greenhouse gas (GHG) emissions, climate change mitigation and adaptation hence contributing to peoples' wellness.

Goal 15: Landscape diversity approach aims at soil fertility restoration, protection of terrestrial ecosystems, reduction of land degradation and promotion of biodiversity conservation. The approach contributes to conservation of soil biodiversity and enhances species diversity in all soil types It is therefore paramount for the farming communities to embrace landscape diversity for its contribution to the wellness of the populations [23].

#### 4. Land degradation, causes and consequences

Land degradation is defined as "the loss of production capacity of land in terms of loss of soil fertility, soil bio-diversity and degradation of natural resources" [24].

Land degradation is a major challenge in both developed and developing countries. It affects ecosystems, food security and the economy of many countries. Human beings play a vital role in land degradation activities [25].

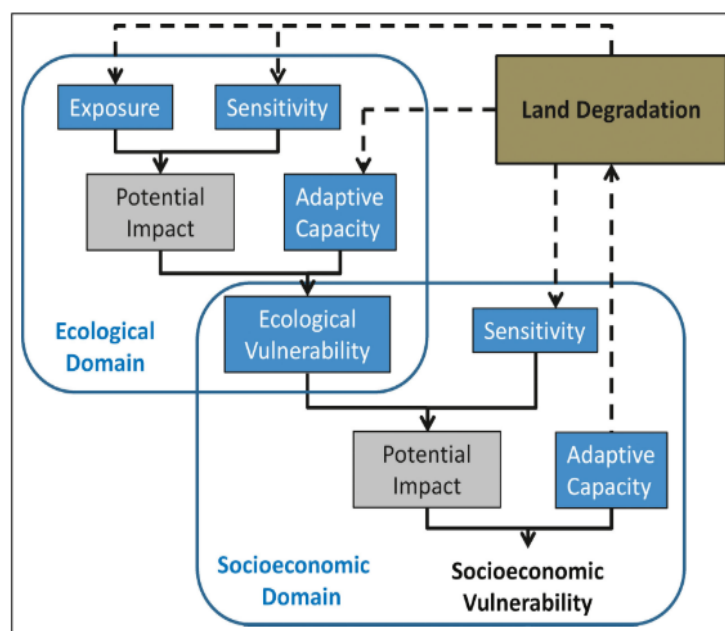
These domains overlap where agroecological, social, and economic processes interact (e.g., in determining the vulnerability of ecosystems to management strategies and the impacts of land degradation). Solid arrows represent links between factors that determine vulnerability and land degradation, dashed arrows represent potential links between vulnerability and land degradation (Source:[26]).



**Figure 2.** Ecosystem sustainability (Source: [27])

**Table 1** Contribution of landscape diversity to sustainable development goals (Source: UNDP 2015)

Goal 1. End all forms of poverty everywhere
Goal 2. End hunger, achieve food security and nutritional improvement, promote sustainable agriculture
Goal 6. Water for all and sanitary availability and sustainable management
Goal 13. Take immediate action Fighting climate change and its consequences
Goal 15. Conservation, restoration, sustainable use of terrestrial ecosystems, sustainable management of forests, combat desertification, prevention and reversal of land degradation and biodiversity loss



**Figure 3.** A framework for conceptualizing the links between land degradation and the vulnerability of agriculture to climate change in the ecological and socioeconomic domains.

The literature has identified several causes of land degradation, most of which are country or region specific. For example, in China, water quality and human disruption following urbanization have been found to be major factors. [28] In the SSA region, major causes of land degradation include population pressure, poverty, legal vulnerabilities, agriculture, urbanization, infrastructure, mining, terrain, deforestation and climate change. [28, 29] In the United States, climate change, along with human disturbance and agriculture, is one of the leading contributors to land degradation. [26] Figure 3 shows the complex relationship between soil degradation and ecosystem functioning. Land degradation affects both ecological and socio-economic areas of the ecosystem and therefore supports relevant services in specific areas [15,17]. Both the adaptability of the ecological domain and the sensitivity of the socio-economic domain are affected by land degradation. In addition, climate change and land degradation affect ecosystems and the services they provide to people, affecting agriculture, food security and the national economy. [26] Land degradation impairs human well-being, and genetic diversity leads to slower national development. This phenomenon has a strong impact on the land and water resources that are the engines of humanity and biodiversity [19-22]. Land degradation has many consequences: pollution, soil infertility, food insecurity, loss of aquatic diversity, floods, droughts, salt levels, human illness, increased poverty, human migration, migration and climate change. Through the increase and the resulting desertification, it will have a serious impact on water resources [20-21]. The effects of land degradation affect climate, population, natural resources and thus genetic diversity on a spatial and temporal scale worldwide. The need for stable and resilient landscapes

Climate change is the major threat to ecosystems and humans across the globe. According to the Fifth Assessment Report of [30], the following observations were made:

- I. The human impact on the climate system is clear, with recent anthropogenic greenhouse gas emissions being the highest ever. Recent climate change has had widespread impacts on human and natural systems.
- II. Climate system warming is evident, with many of the changes observed since the 1950s decades to thousands. It's unprecedented for years. The atmosphere and ocean have warmed, snow and ice have decreased, and sea levels have risen.
- III. Anthropogenic greenhouse gas emissions have increased since before the Industrial Revolution, primarily due to economic and population growth, and are now higher than ever. This has made the atmospheric concentrations of carbon dioxide, methane and nitrous oxide unprecedented, at least in the last 800,000 years. These effects, along with the effects of other anthropogenic factors, have been demonstrated throughout the climate system and are most likely the major cause of warming observed since the mid-20th century.

As a result, climate change has significant implications for landscapes, cropping systems and ecosystems, thereby threatening food security, humanity and biodiversity around the world. In the 21<sup>st</sup> century, climate change is expected to affect the socio-economic conditions of many populations, increase poverty and undermine people's well-being [31]. Ecosystems with

diverse land uses such as forests, wetlands, forests and grasslands survive climate shocks and continue to provide the necessary ecosystem services. Previous studies have shown that cultural landscape sustainability is an important economic activity that promotes national development [23-24]. Proper landscape management is the key to sustainable development to meet the needs of all people of today's and future generations around the world.

Challenges in maintaining a stable and resilient landscape Maintaining a stable and resilient landscape is a complex phenomenon, especially in developing countries. This is because the population is growing faster than ever and human needs are enormous. Socio-economic and political concerns have undermined the maintenance of stable ecosystems in many countries. For example, conflicts in South Sudan, the Democratic Republic of the Congo, Bangladesh, Yemen, and other developing countries have resulted in land degradation and the destruction of many ecosystems as war victims seek ways to survive. [23-27]. In some cases, selfish military officers and key politicians abuse conflicts to promote deforestation by illegally killing large mammals for their own benefit. This is exacerbated by cross-border ecosystems. There, natural resources can only be controlled to a limited extent during conflicts. In waters such as Lake Victoria, conflicts between lake-sharing countries such as Uganda, Tanzania and Kenya are increasing the illegal fishing of small fish [24-26]. In addition, developing countries have limited financial and technical capacity to adapt to climate change. High levels of poverty also increase ecosystem degradation Poor people usually look for ways to earn a living. Their basic needs drive them to destroy ecosystems and extract resources for sale to support their families. Like everyone else, they have to feed, raise their children, and take care of the medical needs of their families. Most of them are redundant, so they have more time to degrade the ecosystem to acquire something they can use to support their families [27-31]. Additionally, they have limited understanding of the value of ecosystems and natural resources in exchange for supporting their families. Greed and corruption are other challenges affecting landscape stability in developing countries. Rich, greedy and corrupt politicians don't care about protecting natural resources or landscape diversity. They are concerned about acquiring and keeping more money in their bank accounts, despite the funds used to acquire it [32-34]. They can sell anyone for money, including killing companions at the expense of funding. Some of the deaths in Uganda in the last decade have been attributed to politicians' corruption and greed. For example, the sale of Mabira Forest ([https://www.newvision.co.ug/new\\_vision/news/1006094/sell-mabira-forest-save](https://www.newvision.co.ug/new_vision/news/1006094/sell-mabira-forest-save)) for sugar cane cultivation was protested and resulted in death. Indian entrepreneurs attributed to the greed and corruption of the president and his corrupt officials. Urbanization and Infrastructure

Development As populations grow in many developing countries, more cities are being established and some are being expanded to increase entrepreneurial opportunities. Improving road networks, mining minerals, building schools and medical centers, and constructing residential and commercial buildings all take place on land, leading to ecosystem degradation [35]. Development is good for human well-being, but it must not come at the expense of ecosystems and natural resources.

## 5. Landscape Diversity and Stability Benefits

Landscape diversity and stability have many benefits and opportunities around the world. Benefits include mitigating climate change by reducing carbon emissions, improving crop production, increasing household incomes for smallholder farmers, conserving soil and water, providing employment opportunities for youth and women, and enhancing biodiversity conservation. includes [36,32]. Landscape diversity enhances the genetic diversity of ecosystems, resulting in a triple win including food security, adaptation and mitigation [37]. It also improves the conservation of natural resources and biodiversity at local, national and global levels. In addition, landscape diversity provides diverse products and farmer incomes from the landscape and protects farmers from unforeseen losses from climate change variability, pests and diseases. The diversity of the landscape avoids the "put your eggs in the same basket" scenario, and in the event of an accident, everything collapses at the expense of the farmer [38-40]. Landscape diversity does not only benefit the user but also the environment and the government. People, environment and biodiversity will all benefit from landscape diversity and it is generally good for the entire universe [15, 41,42].

Land scape agricultural diversity opportunities include: availability of crop genetic diversity to support crop varieties that are pest and disease resistant; production of high yields and adaptive to climatic variations [38, 43-46]. availability of some sustainable agricultural researchers and USA National Centre for Biotechnology Information (NCBI) gene bank for genome resources for crop enhancement; enhanced technology for sustainable agricultural practices such as spring irrigation system and minimum tillage equipment that can be accessed by farmers to promote sustainable agriculture [47]. Furthermore, vibrant research organizations and keen researchers from both national and international bodies such as Consultative Group for International Agricultural Research (CGIR), Food and Agriculture Organization (FAO), Climate Change, Agriculture and Food Security (CCAFS), National Agriculture Research Organization (NARO) and the International Livestock Research Institute (ILRI) promote sustainable climate-smart agriculture research and

practices at all levels [48-53]. Opportunities in the forestry sector include improved forest seeds/seedlings and tree planting capacity building can be obtained from national forest research Institutions.

## 6. Actions for implementing landscape diversification

Diversification of landscape management cannot be achieved single-chandelier's a complex issue that requires complex measures and strategies at all scales and levels. In Europe for example, stakeholders

at all levels and scales are brought on board to plan and undertake initiatives for managing biological and landscape diversity (Figure 4).

The council added together all ministers from 55 EU states to speak about difficulties pertaining to land problems associated with land degradation, making strategic plans, and organic and panorama variety challenges. The excessive-profile dignitaries, instituted a Pan-EU method for the conservation and sustainable use of shared natural sources, after endorsing the Pan-EU biodiversity conservation strategy.

**Many initiatives have been and are being undertaken to address the continuing deterioration of the natural environment. Their capacity would be enhanced and their effectiveness increased when:**

- initiatives cover the whole of Europe;
- biological and landscape diversity is integrated adequately into all social and economic sectors;
- conservation of landscapes is adequately incorporated in the major initiatives dealing with biodiversity;
- subsidiarity, partnership and involvement are incorporated;
- initiatives make use of all mechanisms available, in order to change how society thinks and works in relation to biological and landscape diversity, including: international and national markets and trade policy, multilateral or bilateral funds, fiscal and financial policy, initiatives and programmes, public awareness and participation;
- all the main actors in the economic sectors, the land users, the authorities and the general public are involved;
- the same Strategic principles to achieve goals are implemented, thereby achieving possible synergy.

**Figure 4.** landscape diversity initiatives (source: (Source: [54])

### Strategy aims and objectives:

#### Aims

1. Threats to Europe's biological and landscape diversity are reduced substantially.
2. Resilience of Europe's biological and landscape diversity is increased.
3. Ecological coherence of Europe as a whole is strengthened.
4. Full public involvement in conservation of biological and landscape diversity is assured.

#### Objectives

1. Conservation, enhancement and restoration of key ecosystems, habitats, species and features of the landscape through the creation and effective management of the Pan-European Ecological Network.
2. Sustainable management and use of the positive potential of Europe's biological and landscape diversity through making optimum use of the social and economic opportunities on a national and regional level.
3. Integration of biological and landscape diversity conservation and sustainable use objectives into all sectors managing or affecting such diversity.
4. Improved information on and awareness of biological and landscape diversity issues, and increased public participation in actions to conserve and enhance such diversity.
5. Improved understanding of the state of Europe's biological and landscape diversity and the processes that render them sustainable.
6. Assurance of adequate financial means to implement the Strategy.

**Figure 5.** Aims and objectives of biological and landscape diversity (Source: [54])

**Action Themes**

0. Pan-European action to set up the Strategy process.
1. Establishing the Pan-European Ecological Network.
2. Integration of biological and landscape diversity considerations into sectors.
3. Raising awareness and support with policy makers and the public.
4. Conservation of landscapes.
5. Coastal and marine ecosystems.
6. River ecosystems and related wetlands.
7. Inland wetland ecosystems.
8. Grassland ecosystems.
9. Forest ecosystems.
10. Mountain ecosystems.
11. Action for threatened species.

**Figure 6.** landscape diversity Action themes (Source: [54])

The strategy was shared with stakeholders at the grassroots level. With zero-tolerance to corruption, the continent has diverse landscapes and different in spite of the loss of many natural sources consisting of the wooded area. In collaboration with the United Nations Environmental Program (UNEP), the employer for Organization for Economic Co-operation and Development (OECD) and International Union for Conservation of Nature (IUCN), and all national and worldwide stakeholders, a workshop was organised to design strategic aims and conservation objectives were presented (Figure 5).

The landscape diversity strategy was derived from the previous reports for Europe's Environment: The Dobříš Assessment' and IUCN Parks for Life: Action for Protected Areas in Europe. This was built on 10 thematic areas (Figure 6) [54]. Thematic areas point out the implementing agency and major ecosystems of concern in landscape diversity implementation strategy.

Based on the landscape context for each country, biological and landscape diversity strategic plan can be drawn for the wellbeing of their people, the country and natural resources based on their local environmental, available financial capital, technical capacity and political will for investment [13,55-57].

## 7. Conclusions

Landscape diversity is critical for its sustainability and resilience. It enhances conservation of soil, water, genetic diversity for flora, fauna and microorganisms of all types. It can be approach from the ecosystem perspective to enhance the conservation of genetic diversity at all scales and levels. The approach is essential for landscape sustainability, resilience and the welfare of human beings. Landscape diversity can be attained basing on landscape management strategic plans drawn by stakeholders from all levels and at all scales. Networking and collaboration with both national and international agencies, private sector, NGOs and conservation-oriented institutions can help in advancing

the cause for landscape diversity in order to enhance landscape resilience across the globe. As climate continues to change and human population continues to increase, it necessitates the diversity landscape to meet the growing food and nutritional security and mitigate impacts of climate change in all landscapes across the globe.

## Recommendations

The following recommendations are drawn from the review:

- i. Landscape management is a complex issue that requires complex solutions. There is need to involve all stakeholders in drawing and implementing landscape management strategic plans at all levels and scales
- ii. Laws and policies should be enacted and ensure effective implementation especially in developing countries that govern landscape diversity approach to enhance food security and conservation of genetic diversity
- iii. Good governance associated with transparency, proper accountability, corruption-free and patriotism should be embraced in all developing countries to implement landscape diversity approached for enhancing UN sustainable development goals
- iv. Platforms should be established that encourage networking and collaboration of developing and developed countries, conservation agencies, NGOs, private sector and researchers for dissemination of landscape diversity and its resilience to create awareness about the same among stakeholders
- v. Intensive research needs to be supported and conducted to establish the benefits of landscape diversity and disseminate findings to all stakeholders who will take action in

implementation of appropriate strategies that can enhance landscape diversity

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All the data that was reviewed for this paper have been published elsewhere. References including doi codes, as available, are availed accordingly.

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