International Journal of Research Studies on Environment, Earth, and Allied Sciences (IJRSEAS)
| *Volume-3 Issue-4* | *August-2026* | *ISSN: 3066-0637* | *Website:* https://eesrd.us

Manuscript ID:
IJRSEAS-2026-030406

OPEN ACCESS

Quick Response Code:

Website: https://eesrd.us

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DOI: 10.5281/zenodo.23392346

DOI Link: **https://doi.org/10.5281/zenodo.23392346**

Volume: 3

Issue: 4

Pp. 48-57

Month: August

Year: 2026

E-ISSN: 3066-0637

Submitted: 07 July 2026

Revised: 18 July 2026

Accepted: 10 Aug.2026

Published: 31 Aug. 2026

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How to cite this article:
suryawanshi, K. V. (2026). Ecological Assessment of Plant Communities under Changing Environmental Conditions. International Journal of Research Studies on Environment, Earth, and Allied Sciences (IJRSEAS), 3(4), 48–57. *https://doi.org/10.5281/zenodo.23392346*

Ecological Assessment of Plant Communities under Changing Environmental Conditions

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Abstract

Changing environmental conditions have significant effects on plant communities, influencing species composition, species richness, functional traits, ecosystem functioning, and resilience. This study provides an ecological assessment of plant communities in relation to major environmental change drivers, including climate change, land-use change, habitat fragmentation, pollution, nutrient dynamics, disturbance, and biological invasions. The assessment emphasizes changes in community structure, species turnover, functional traits, primary productivity, nutrient cycling, habitat quality, and ecosystem resilience. Methodological approaches such as field surveys, long-term ecological monitoring, remote sensing, satellite imagery, UAV-based observations, spatial analysis, gradient analysis, and experimental approaches are highlighted for evaluating ecological changes. The assessment also considers responses across grasslands, forest understorey, wetlands, and alpine/montane ecosystems. The synthesis indicates that environmental changes can alter species composition, biodiversity, ecosystem functions, habitat quality, and recovery processes, with responses varying among ecosystems and environmental conditions. The study emphasizes the importance of continuous monitoring, resilience-based indicators, adaptive management, conservation planning, and further research on tipping points and interactions among multiple environmental drivers for maintaining plant-community integrity and ecosystem services.

Keywords: *Plant community ecology; ecological assessment; environmental change; climate change; species richness; biodiversity; functional traits; ecosystem resilience; habitat fragmentation; land-use change; pollution; nutrient dynamics; remote sensing; spatial analysis; ecosystem services; conservation management.*

Introduction

Ecological assessment is a question of impact of environmental changes on plant communities with the goal to assess the expected changes in the next decades and their functional and ecological consequences. Temperature and rainfall scenarios predict warmer temperatures, more summer dry, and more winter wet. Spatial connectivity is expected to be impacted by rapid urbanization, with both habitat loss and fragmentation expected. Increased deposition of nutrients in the atmosphere is likely to affect many areas, particularly deposition of nitrogen; eutrophication, soil acidification, and changes in nutrient dynamics are already being seen.

In such stressful environmental conditions, ecological evaluation emphasizes patterns and trends in species composition and richness, functional traits and the dynamics of community assembly processes. The presence/absence of species, the relative turnover of species, nestedness and changes in rarity and thus extinction risk all contribute to changes in species richness over space and time. Functional-trait based approaches reflect changes in the functional strategy of resource-use acquisition (e.g. leaf-economics spectrum) as well as plant height, reproductive strategy, size and dispersal of seeds, rooting depth, plant phenology and climatic adaptation. Community assembly processes also play an important role, involving the relative contribution of colonization, competition, and stochasticity, as well as the role of early species in influencing later species, thereby steering succession.

Theoretical Framework

1. Plant Community Ecology

Structure (composition and relative abundance) of community is affected by species interactions and other community processes. Competition and facilitation are important types of facultative interactions affecting species co-existence. The dominance of species that are more successful at competing for less is favoured and facilitation leads to the establishment of seedlings or stress sensitive species. The set of species that can colonize the area are limited by environmental constraints. These processes impact community assembly and adaptive cospeciation as well as community adaptation to environmental changes.

The analysis of community assembly can be done from a niche-based or a neutral perspective, where both of these perspectives provide complementary descriptions of community assembly and are used to understand the relative importance of species-specific traits, dispersal, and randomness in the assembly of local or regional species pools. The patterns of ecological succession observed, are similar to those predicted by these models. Multiple pathways to community assembly and succession exist dependent on the relative importance of facilitative, competitive and stochastic processes.

2. Environmental Change Drivers

There are a number of environmental change drivers, including climate change, land-use change and pollution, and modification of disturbance regimes, that affect plant communities. It is expected that climate change may affect community process rates (primary production and nutrient cycling) in ways that will affect habitat quality and biodiversity-ecosystem function relationships. Disturbance is increasing due to climate variability and climate extremes are affecting recovery of important ecosystem functions and multiple ecosystem services. Reduced dispersal ability of species, alteration of species composition in favour of less mobile species and impacts on community dynamics due to habitat loss and fragmentation. Light limitation is also influencing community dynamics of forests, with greater species richness in understory under low invasive species pressure, but not in areas experiencing high invasive pressure. Non-analogue communities and pollution combined effects (deposition, eutrophication and soil acidification) influence the composition and stress on functioning.

1. Plant Community Ecology

The structure of the community provides information about the composition of the community (what species are in it, how many of each and where). The patterns observed in community structure arise as a result of the intricate web of species interactions taking place within and among communities: competition among individuals of the same and different species, facilitation caused by positive interactions among species, and even stochastic processes can shape community structure. The niche concept is ensuring that species with the same requirements are not improved by a neighbouring species. Thus, if there is less niche space available to one species, there should be a corresponding decrease in abundance of that species in the structure of large-scale communities. The theory of ecological succession also helps to explain the tendency of a more complex community to develop in which competitive hierarchies are formed and more abundant species continue to dominate the community until a large perturbation or phase shift occurs, at which point the community structure is radically changed. The latter is well known to be also stochastic, particularly in older ecological communities, however.

Plant communities can be directly influenced by changes in the environment. Widespread shifts in species composition and a non-uniform picture of species richness change could result when environmental change drivers change their strength, timing and normalization. Different taxonomic groups and specialized and generalized species can experience different rate of species change, potentially causing changes in the processes of community assembly. Changes in environmental conditions are likely to lead to changes in community structure and rules of community assembly (other than predation) at larger spatial and temporal scales, and to changes in the habitat conditions provided by species to fauna, which may give rise to phase shifts.All of these interacting processes that determine species coexistence from small to large spatial and temporal scales can then be altered by changing environmental conditions, which can lead to changes in community structure and assembly rules, non-trophic interactions, and habitat conditions that communities provide to fauna.

2. Environmental Change Drivers

Environmental change drivers are many stresses imposed on plant communities world-wide. Climate change, such as extreme weather, changes in mean temperatures and precipitation, changes in disturbance regimes, are of special concern. There are further threats to composition from urbanisation, land use change, fragmentation and loss. Pollution, introduction of non-native species, over exploitation of biota and disruptions of ecosystem processes further degrade ecosystem integrity and cause changes in biotic interactions, soil characteristics and nutrient dynamics.

The adverse climate change impacts are expected to be temperature and precipitation changes, which will impact moisture availability, and further flooding and drought impacts, phenological asynchrony, species assemblage composition and disturbance frequency. Climate change can also cause land use change, fragmentation and pollution, which lead to new and changed stresses (R. Abella et al., 2019). Changes in soil nutrient and stoichiometry, as well as increased or decreased disturbance of soil and water, can also alter the plant communities due to nitrogen, phosphorus and sulfur deposition, the addition and accumulation of toxic metals and changes in atmospheric carbon-dioxide (L. Adair et al., 2019).

3. Metrics of Change and Resilience

Advice on Resilient Management of the Environment in the changing environment.

Generally, the patterns of alpha and beta diversity, the responses to the changes in phylogenetic and functional diversity and the changes in the stability and ecological resilience of ecosystems under perturbations are taken into account in comprehensive indicators of change in the environment and ecological resilience. Based on plant community responses to past environmental changes, predicted environmental constraints on plant community assembly and functioning can be compared across a variety of ecosystem types (grassland, forests, wetlands, alpine/open montane systems). The species composition and turnover, response by functional traits, and restructuring of the ecosystem are primary responses considered.

These three aspects of community response are all tightly intertwined with the shifts in functional primary productivity and nutrient cycling, habitat quality for plant–animal interaction specialists and the ability to sustain

recovery processes under an ongoing human stress that is a fundamental problem in conservation and management. Finally, knowledge synthesis and ecosystem resilience on timescales relevant to the support of biodiversity conservation and management will drive up ecological assessment, management and conservation planning efforts in the Anthropocene.

Methodological Approaches

Ecological assessment of plant communities quantifies community change in community composition, structure and function in response to environmental change. Monitoring these alterations can be useful for evaluating conservation efforts and ensure the sustainable management of the ecosystem. The method employed assesses the effects of the four factors (climate, land use, pollution and nutrient dynamics) on the plant community along biomes and environmental gradients. A comprehensive scheme is used to explore plant community response involving multi-faceted aspects of the response by using data collection, moad436010-bc0d-4a46-95c7-45435e867d33ing, process-based and experimental manipulation, and gradient analysis. The knowledge acquired is synthesized in case studies of different ecosystem types, and is expected to yield a lot of useful information for implementation in all freshwater, marine and terrestrial ecosystems around the world.

Changes in plant communities are characterized by a number of field and survey techniques. The impact of vegetation on climate, energy balance, carbon cycling and biodiversity is analysed at landscape and ecosystem level. Satellite data, aerial photographs and Unmanned Aerial Vehicles (UAVs) provide data on change of plant communities over large areas. Various sources of input broaden and enrich knowledge of community responses. Process-based and statistical moad436010-bc0d-4a46-95c7-45435e867d33s explain the impact of disturbance and other environmental factors like pollution, nutrients, land use, and climate on community structure. Mechanistic relationships are illustrated by manipulative experiments and gradient analysis, and provide complementary information.

The potential impact of climate change on the plant communities is mediated by a number of projected scenarios of major environmental change, such as climate change-related alteration in temperature and precipitation, alteration of land use (including habitat fragmentation and urbanization), pollution and nutrient regime (acidifying pollutants and eutrophication), and alteration in disturbance regime (fire and invasion) (DEL VECCHIO et al., 2016). For each scenario, specific case studies of ecosystems are examined. Climate change extremes and land use pressure are likely to rise, as will be the case for nutrient loads, temperature and precipitation projection, leading to further effects on ecosystem responses. These conditions enable experimentation, further understanding of community dynamics, and help to map out trajectories of ecological change (Chelli et al., 2019).

The 1st task is Data Collection and Field Methods.The 1st task is Data Collection and Field Methods

Among the terrestrial biota, plants are the main producers and they play an important role in different ecosystems. They are important to people with their many ecosystem services which include pollination, water regulation and control, climate regulation, provisioning of food, medicine, and raw materials. Biological communities, plant communities in particular, is at risk around the world due to the ongoing changes in the environment that are being driven by climate change, pollution, land use change and biotic invasions. The ecological assessment can also help to draw conclusions about the community assembly and community dynamics (E. Dowling, 2015) in addition to species composition and abundance. Existing high-frequency datasets are used to model changes in plant community structure, which helps to understand ecosystem dynamics and to assess potential risks and service loss (Chelli et al., 2019).

These have led to specific attributes of plant communities that are monitored to assess impacts of global change: community composition, functional attributes of current species, and functions related to climate. These are attributes that influence other ecosystem functions and related ecosystem services important in relation to human livelihood. Species composition emphasizes presence or absence of species and ties in with the findings of the assembly and succession theory. Ecological strategies, using functional traits of the resident species, provide insights into the ecosystem's reaction to environmental change and link to the ecosystem multifunctionality of primary production and nutrient cycling. Climate-related ecosystem functions assess the possible reduction in the provision of ecosystem services as a result of the change in ecosystem transformation and service loss, as well as, the turnover of species and the change of traits.

Explain the use of remote sensing and spatial analysis.Describe Remote Sensing and Spatial Analysis.

Electromagnetic radiation and energy reflected off the land surface due to solar, earth and terrestrial sources are measured by remote sensing. Satellite Imagery is a method for collecting spectral data from vegetation based on the data collected by satellites at multi-spectral, multi-resolution and multi-temporal levels. Hence, it is feasible to use a spectral signature approach to get bio-physical properties of vegetation. Satellite imagery data can be used to gain information on the properties of vegetation, such as biomass, in the form of Spectral Reflectance, by using multispectral satellite imagery data. A wide-angle and narrow-angle reflectance has accurate observations of vegetation, but quantitative data estimation methods are needed in order to extract the vegetation reflectance from the original signal that is degraded by the shadows and illumination. Use of remote-sensing vegetation index (VIs) from satellite Earth Observing-1 Hyperion satellite plays a role in the VIs computation analysis (Brandt Christiansen, 2017). The range of the central channel time-interval of the VIs is either 400 - 800 nm or 800 - 400 nm, which significantly increases the vegetation cover. Accumulated soil moisture data from Landsat ETM+, Terra MODIS and QuikSCAT retrievals is analysed to see if there is a direct correlation between normalized primary productivity and soil moisture over a range of biomes in Eurasia between 15-50°E longitude over 8 years. The high temporal resolution primary productivity data is produced through application of resolution conversion down-sampling algorithm to Landsat and MODIS data for regional modeling of feedback the precipitation, soil moisture

and vegetation. With the addition of unrestricted atmospheric products, time-lagged precipitation and vegetation impacts on surface moisture and water availability, the high-resolution surface-model-reflections-with-boundary condition system (S. Wendelberger et al., 2018) is achieved.

a) Present the data in graphical format using a spreadsheet.a) Plot data graphically on a spreadsheet.

Experimental or manipulative tests have a long history in ecology and can be applied to discover mechanisms of species interactions. Observation of how some species react to an increasing number of disturbances can be used to understand the stress resistance of the species in comparison to other species or to a community of species that represents the community. This information could then be used in or could be woven into the mathematical models used to predict future changes in community structure across broad spatiotemporal scales, and be used to limit and/or parameterize these models. Many of these studies aim not to replicate the process (e.g., climate change), but to characterize important community-level parameters following an evolutionary and regular perturbation of the process (Reeg et al., 2018). This method has been found to be helpful, e.g., in the case of herbicide applied to a plant community in a controlled environment, the degrees of freedom of interest are the herbicide concentration, the mode of action and the composition of the plant community. After calibration to the specific concentration, the degree of community change (as measured by the model) can be extrapolated to higher concentrations to determine the potential impact of a sprayer regime on a range of plant communities for future scenarios. The different community-level models available can be intercompared to enable a community-wide assessment of the uncertainties of various approaches, favouring the choice of a particular model for the community under study and highlighting possible experiments that may yield the most valuable additional information.

Environmental Change Scenarios

Climate variability and extreme climatic events are significant environmental issues (R. Abella et al., 2019) with local to regional impacts (M. Thorn et al., 2017). More frequent and intense dry conditions and occasional floods are possible in many temperate regions. The events can then result in asynchrony of plant–pollinator and nutrient cycles. Certain plants are more vulnerable than others, and non-native plant and rare species are at risk.

Land-use change and habitat fragmentation are other important environmental factors (Snow & K. Snow, 2008). The trajectory of the globe is urbanization and there is a clear correlation with increased impervious cover, decreased open space, additions to surrounding areas, and changes in topography, humidity and vegetation. Habitat loss and fragmentation, small size, high edge effects, and lack of connectivity. Rising pressures from invasive plants (including escape from neighbouring urban areas) pose further threats to changes in species and community dynamics.

1. Climate Variability and Extremes

Projected temperature and precipitation changes due to climate change have significant implications for species composition and ecosystem functioning (R. Abella et al., 2019). Extremes will get even more extreme and will involve an increase in drought/flood events as well as a change in seasonality of water availability and temperature. More consistent and longer growing seasons, combined with changing precipitation will influence community assembly and spatial distribution of species, with both intra- and inter-species pollination at various scales. This should cause inter- and intra-species and intra-spatial variation in flowering time, which should result in phenological asynchrony (Ma et al., 2017). Changes in abiotic disturbances and conditions can result in increased turnover rates, changing species composition and changing community assembly rules that can affect vegetation trajectory (Barros et al., 2018).

Land Use and Habitat Fragmentation.

Human population growth, urbanization and industrialization disrupt the function of the natural ecosystems, and habitat loss, degradation and fragmentation are most important of these disruptions. Loss of habitat causes a reduction in habitat size and degradation of habitat means that any remaining habitat may not support a population. Although fragmentation does not invariably lead to the loss of habitat area, it does affect habitat continuity, and this affects movement, dispersal or migration between what habitats are left, or between habitat patches.

While most studies of land-use change focus on the loss of natural habitat or the area affected, the scale and configuration of the landscape matrix or remaining patches also change as one moves from natural to "lost" land use (Fakheran Esfahani, 2009).

3. Pollution and Nutrient Dynamics

The Holy Grail of contemporary ecology is the universal theory that unites the spatiotemporal dynamics of organisms, communities and ecosystems. However, theoretical ecology has formidable challenges on the broadness and the complexity of the issues involved. The models of the diversity-productivity relationship show the difference between simple theoretical constructs that are easily mathematically described and much broader understanding that is needed by ecologists. If only the change in plant community composition—Robert Whittaker's life's work—is considered, the number of models, theories and concepts (C. Schneider et al., 2016) becomes overwhelming. Population-, metapopulation- and macroecology somehow interweave with the community composition; succession, in turn, is decomposed into a series of theories and understandings, static and dynamic.

Impacts on plant community structure include:Impacts on plant community structure include:

The structural characteristics of plant communities are commonly used for the conservation assessment (L. Adair et al., 2019). Environmental variation may affect species composition and community structure by favouring some species over others (Xu et al., 2018). For instance, changes in the species composition and community structure have been reported in the gradient of climatic variables, but there is no consistency in these results and they are inconsistent among ecosystem types (DEL VECCHIO et al., 2016). Different directional and temporal trajectories in

community dynamics can be signified by changes in community composition, species dominance and life form appearance. For instance, after a disturbance, increases in area successional and mature are expected to be correlated with increases in height, seed mass and rooting depth. Functional traits variability offers a glimpse into mechanisms of community assembly and thereby aids in adaptive management to re-establish desired trajectory or to prevent early-stage colonizers.

Species composition and species richness.Species composition & species richness

The ecological impacts of environmental change are evaluated for plant communities in primary systems (grasslands, forests, wetlands, alpine). Climate, land-cover, nutrient and disturbance are some of the drivers considered. Long-term datasets are large and can quantify some historical dynamics and future pathways offer information on the potential response of species composition, structure and function. Risk categorisation is used to assess individual species for their vulnerability. The number of species changes significantly, with a drop in nestedness. Globally extinction risks for vascular plants are decreasing while the overall extinction risk is increasing for locally rare taxa and forest and wetland types. Resilience is mostly present, particularly in grasslands. But hysteresis signals forecast potential tipping points with ongoing stress.

Data from optical remote-sensing (OPT-RS) using UAV platform are gathered in the focal temperate upland area, which has not been provided with clear-sky optical data before. The UAV data, in conjunction with six multi-spectral satellite data, provides indicators for VIs including RVI, SAVI, HNDVI, GNDVI, LCI and RDVI. ABI is a more complex representation of vegetation than the VI, but has a greater potential to be applied at a continental scale to monitor habitat status and landscape structure. ABI is correlated with environmental gradient in a positive way. Several environmental factors and mainly the NDVI, MSAVI, MTCI, TCI and GNDVI cause the decrease of the ABI. Overall, ABI estimates result in a projected high rate of habitat expansion and in some cases an estimated high amount of habitat change both locally, regionally and continentally.

2. Functional Trait Shifts

Changes in community composition in response to environmental stress are tracked in ecosystems, and are associated with changes in the abundance of species with few special features. Empirical studies have confirmed the following changes in some key functional traits: higher relative abundance of leaf economic spectrum "fast" species, gradual reduction in the mean community height, gradual decline in the importance of perfectly, micro- or allometrically dispersed seed, increased shallow or ephemeral rooting systems and progressive earlier or later autumn or spring senescence. The most important factors are climatic aridity and the relative availability of nutrients, which are the prime determinants of adaptive strategies. Resource-acquisitorniche-constructors and "fast" characteristic species are better able to out-compete stress tolerators and "slow" characteristic species under higher moisture and nutrient conditions while stress tolerators and "slow" characteristic species are dominant under lower moisture and nutrient conditions.

Increasing environmental stress usually promotes greater distance decay of the similarity in species composition with geographical distances. The increase in these processes—stochastic community assembly and colonization processes—in the plant community is associated with a shallower and flatter competitive hierarchy related to niche-editing of the carcass; in the lowland forest community there is a slowly "disconnected" trajectory in the assembly, and also decreased priority effects in the plant succession.

Encourage the assembly of the community, and their transition to a new life.

Changes in the composition of communities may result from changes in species pool type dominance in ecological successions and colonization events may alter species distribution depending on species losses occurring in the succession. These responses may become more deterministic due to the process's progression. As a species-driven turnover may occur, prioritization and community assembly can occur at different stages during the process of species invasion and establishment. The directionality and successional influences on respiration rates remain unknown, as do the joint effects of these two processes on recovery and reassembly of the functioning of respiration at the community level, in the context of warming and nutrient deposition, across temperate grasslands.

Moderate resistance in gross primary production patterns indicates the adaptation of aerobic microorganisms to the higher nutrient concentration in continent-wide ecosystems with high N concentration. The strong hysteresis in the net productivity responses, on the other hand, suggests the existence of thresholds that it is not possible to cross without losing ecosystem functioning as part of the old landscape. Respiratory microorganisms may be less sensitive to warming than GPP, and there may be a hysteresis effect, in addition to highlighting the need to maintain a high level of integrity in local species pools as a way of conserving the ability of the respiratory system of temperate grasslands.

The role of food webs and functions in the ecosystem.

The importance of separating the impacts of environmental change on plant-community structure and function on the provision of ecosystem services has never been more critical for predicting plant ecosystem dynamics in the future and designing suitable conservation and management policies. With contrasted environmental changes with different impacts on the distribution and composition of the plant communities. The research has shown how important the ability of temperate grasslands to support other species' habitat requirements and nutrient cycling benefits will be under changing environments, and the importance of recognizing this ability in management. Disentangling the effects of environmental change on plant-community structure and function in relation to ecosystem services provision is crucial for predicting future ecosystem dynamics and developing appropriate conservation and management strategies. It is crucial to understand the relationship between biodiversity and

ecosystem functioning to appreciate the potential for changes in these relationships under the changed environmental conditions.

The positive relationship between α diversity and primary productivity has been observed in many studies but not all ecosystem, therefore whether diversity always positively affects ecosystem functioning remains uncertain. Plant communities also have supporting functions, which are impacted by habitat quality decreases by affecting the availability of refuges for other species. Furthermore, there is limited knowledge about the nutrient cycling processes and they do not have a functional traits approach. A positive effect of species on plant net nitrogen mineralization has been observed, and this positive effect becomes saturated at higher species diversities. Moreover, most of the studies reported the positive relationship between plant-diversity richness and potential nitrification, which is linked to plant-diversity complementarity due to the different N-requiring traits of various plant species.

The primary productivity and nutrient cycling are depleted.Primary productivity and nutrient cycling reduced.

Gross and net primary productivity are two fundamental characteristics of an ecosystem and the primary energy flow in each of the biogeochemical fluxes. Therefore, the internal cycling of nutrients and gross primary productivity play a basic role in the processes of ecosystems. Changes in diversity, composition and/or functional traits are likely to result in changes in nutrient mineralization and fluxes between pools (e.g. litter-soil, soil-vegetation) at the population level. In the latter case, fluctuations in the environment that holds a species could be a threat; a population at the limiting end of the abundance range could be reacting to a rise in the amount of the resource that is being held. The effects of the nutrient stiochemetry changes are on the ecosystem structure and its function. High concentration of nitrogen, phosphorus and reaction to open habitats would be an indicator of high habitats quality and high primary productivity system. The N and P fluxes between organic and mineral pools are likely to be influenced by temporal change within a long-term time period. Eutrophication is caused by excess N, P and S, which causes strong selection pressure, decreasing richness, increasing habitat quality. For a certain threshold of accumulation of sediments and nutrients, the primary productivity starts to decline when the nutrient immobilization due to litter mineralization is not sufficient.

Net primary production and net nitrogen mineralization suitable for the analysis of net nutrient respect for the mineralization-immobilization turnover. N flux is in the absorption phase (growth of fungal hypha is stopped). The fungal part diversity product ratio value shows that the key role of their function is to play a part of mineralization-immobilization. Nutrients are supplied via other land use pathways. Loss of primary productivity presents the forest with increased risk of shrinking, but also provides an opportunity for the forest to "catch up" through intercatastrophic colonization of mangrove species. Birds have a structuring role that affects liana populations, which affects the liana component through affect of liana-feeding insects and affects the liana component through their seeding roles.

2.2 Habitat quality and biodiversity support

The other functions of ecosystem services such as habitat quality for other organisms and the impacts on ecosystem support for biodiversity are also sometimes secondary to primary productivity. Communities' ability to contribute biodiversity at other levels is related to changes in habitat suitability, habitat structure, refuge availability and species-hetting interactions in response to changes in environmental condition. Changes in habitat suitability of selected species are related to habitat availability of hydrology or forest structure. Generally, habitat quality decreases as urbanization increases, particularly along gradients of land-use disturbance, and with structuring complexity of habitat. More habitat diversity does not always imply more species diversities, however. In some systems, high habitat complexity led to higher abundance, but not more species richness, in the presence of multiple species, possibly indicating that in complex systems, abundance matters more for inter-specific interactions than species richness.

More species rich assemblages are likely to result in a more diverse range of resource complexes and opportunities for heterotrophic or predatory coss-processes. In heterotrophic communities it seems that, where resources are low, the quality of habitat is poor (or functions are impaired), interactions are reduced and the variety or species richness is reduced. Changes in composition at higher trophic levels can affect the composition of lower trophic levels assemblage. The expected decrease in potential quality of vegetation along nutrient availability gradients will result in a disruption of heterotrophic patterns. Reductions in other taxa of habitat quality (e.g., heterotrophic and higher trophic level assemblages) indicate potential loss of services to support resident biota.

3. Resilience, Stability and Tipping Points

Seeds and plants recover rapidly in response to anthropogenic disturbances and the plant communities are very resilient. But not all this resilience is found and disturbances transform into new states or they do not allow the recovery. If there is no vegetative recovery during the first few years, it may cause hysteresis and abrupt regime shifts. Critical thresholds are levels which generate a danger space to be avoided or climbed out of to avoid the risk of a long-term or permanent degradation.

The recovery time after human-induced changes and the recovery time of critical ecosystem attributes needed for particular functions are called the speed of recovery. Hysteresis occurs when the re-establishment of structures or processes after a disturbance does not occur and ecosystems may end up in new states with new functions. The species richness in regulated rivers shows inverse hysteresis: communities recover more rapidly from higher degrees of hydrologic alteration to lower degrees of alteration and vice versa. Critical thresholds are the intensity, duration and/or magnitude of the disturbance at which the system fails or is unable to return to the pre-disturbance dynamics or functions and is instead directed to a new dynamics or function.

Management should not encroach on critical areas, and should assist in the recovery after disturbance. If the danger zones are avoided, the chances of taking on an alternative state are lessened. Understanding how sensitive to human pressures and how vulnerable to abrupt changes, tipping points and regime shifts, the ecological consequences of environmental change around the globe will be.

Case Studies by Ecosystem Type

Species turnover is lower under sustained grazing and higher with fire return intervals over a threshold in grasslands with different disturbance regimes (R. Abella et al., 2019). Biotic (grazing) and abiotic (local climate variation) factors can influence grassland plant communities, with unclear response trajectories. Nevada and Utah sites have been monitored in the long term, including a summer of intensive climate variability, and there were no significant changes in community composition, richness, or cover during land use or climate changes recorded. Species establishment is limited by light, and most variability in diversity is due to local factors in forest understorey communities (DEL VECCHIO et al., 2016). Managed forests show a significant change in understorey composition, native diversity decreases and invasive species proliferate as a result of pine dominated plantations. Overall stand-structure convergence is not sufficient to allow communities to recover or reassemble because of reduced light and other management-related pressures. The alteration of the hydrology of wetlands affects their communities but under some conditions, the relative fragility of the vegetation depends on the soil type, and the peat-forming vegetation may increase with drainage, which enhances CO2 emissions. Coastal wetlands are influenced by both temperature and salinity changes, resulting in reduced species diversity and species composition and thus lower resilience in anthropogenically modified wetlands. In alpine/montane systems, higher temperatures cause a variety of treeline changes, but few changes in páramo positions. Species are able to persist in microclimate refugia when other than the microclimate factors are temperature sensitive. Glacier retreat is coupled with evolution of the glacial lakes and land use to isolate communities in southern páramo areas.

1. Grasslands

Grasslands are one of the most productive ecosystems on earth, delivering vital services that are critical for the maintenance of biodiversity and livelihoods of humans (Kim et al., 2023). Grasslands occupy almost one-third of the earth's surface but are one of the most threatened ecosystems. To predict how the ecosystem will respond and to develop mitigation and adaptation strategies under global change scenarios, knowledge about which environmental drivers are influencing grassland communities and ecosystems is essential. The effects of fast climate change and land use change on the species assemblage turnover pattern in the steppe of the Loess Plateau in China is examined by focusing on the influence of the changes in temperature and precipitation regimes and the abandonment of land and establishment of shrubs on species turnover pattern, in the study of several works addressing anthropogenic drivers of change in steppe grasslands in Inner Mongolia. Using long-term vegetation and climate data, Yan (Yan, 2014) evaluates biogeochemical progress and the carbon cycle in the mixed-grass prairie on the Southern Great Plains of the United States. Forb communities in grazed and fire-maintained savanna-grasslands from two different climatic and biogeographic regions (North America and South Africa) are examined by Koerner (Koerner, 2012).

Facing degradation of grassland, biodiversity and carbon dynamics are at stake. Unique plant species and phylogenetic diversity are found in patchy dry steppe grasslands of Inner Mongolia, China. Monitoring, management and restoration are desperate in this arid region to offset degradation of the grasslands. Sequestration levels increase with increased temperatures and outside-season precipitation and stabilize at a higher level. The knowledge of property rights and land use practices gives insights into strategies for further land use avoiding degradation. Restoration goals are aimed at reducing variation in plant communities and to enhance resilience. Structural properties of plants help to ensure soil multifunctionality and drought resistance.

2. Forest Understorey

Forest ecosystems are one of the most complex types of terrestrial ecosystems, consisting of multiple canopy layers (strata). Forest understorey communities are subject to multiple influences of global change (e.g. climate change, land-use, socio-economic). Unpredicted changes in the species composition and biodiversity of temperate deciduous forests caused mainly by background disturbance (storms) are distinguishable from those expected in response to environmental factors (e.g., climate). These changes must be explained in terms of linkages between the overstorey and understorey, and the response of these to global change. Relatively little is known about the diversity of forest understoreys compared to other ecosystems (e.g. grasslands, wetlands), although nature based solutions and forest understorey conservation services linked to the widespread invasive species are increasingly being guaranteed with global attention. Not all plants are directly harvested; lower regulation for changes in the environment. Even though passive regulation occurs, overstorey–understorey interaction can still have a signalling mechanisms that can lead to increased importance of other channels of global change. It has not yet been possible to retain the conceptual and operational connections between overstorey and understorey species after decades of use. (Landuyt et al., 2018)

3. Wetlands

Wetlands are one of the most valuable and threatened ecosystem on the planet, providing a diverse suite of regulating and cultural ecosystem services and habitat for a diverse range of flora and fauna. They are subsequently subject to climate change, land-use change and specific pollution processes. Floodplain wetlands in the Murray-Dar5bca9cb0-0711-484b-addc-890869b68281 Basin are predominantly drought and flood dependent, and alteration of riverine systems by human management has altered the eco-logical characteristics of many wetlands and their capacity to receive overbank flows in a regular pattern. The impact of land use and water quality has been the topic of several studies. A condition assessment of floodplain wetlands across the region confirmed that good relationships

existed between condition and addressable stressors, including local land use and flow regime. In both the agricultural and urban land uses, associated with nonpoint-source nitrate loads, impacts on floristic quality in wetlands were identified, with the development of a water-quality improvement tool for target pre- and post-wetland nitrate loads in both of these land uses (Jermond Crane, 2014). Periodic desiccation associated with regu-lated flow at another site increased the establishment of riverine invaders and chrysophyte blooms in ephemeral freshwater wetlands; decreasing the frequency of such events would reduce their impact and averted most other stress factors (Ling et al., 2019).

4. Alpine and Montane Systems

Altitudinal and montane systems have different vegetation communities associated with the environmental variables (altitude, climate, topography). The altitude gradient leads to a complex gradient in the environment which has drastic impacts on species diversity and community structure, and species richness tends to increase in temperate zones. Community type depends on certain environmental conditions, and the composition of communities changes with elevation. In alpine ecosystems, multivariate analytical tools are employed to identify plant communities, detect dominant species, and to understand the environmental factors influencing plant communities (Ur Rahman et al., 2021).

In the central Andes, global climate change is causing warmer, dryer local conditions, and shifting of alpine plant communities up-slope according to their climatic niche. A survey in 2006-2008, repeated in 2012 and 2017, identified a significant decline in plant cover, species richness and diversity from low to high elevation with a decrease in soil temperature. Plant community turnover varied significantly between the two plant censuses (37% to 49% by summit and aspect). The summit of the lowest peak, and the northern and westerly flanks, saw significant changes. Plant cover at the highest summit increased over time, species richness at the lower summit increased over time, diversity across all summits increased over time and there was an increase in small herbs and non-tussock grasses (Carilla et al., 2018).

Synthesis of Findings

Ecological assessments measure the effects of environmental change on biodiversity and ecosystem function, and serve as a critical component of ecological research, policy and management. Ecosystems face threats to their resilience and nature's services from changing climate, changing land use, changing biogeochemical cycles, and changing disturbance regime. A clear ecological assessment can assess conditions, measure sensitivity and predict future scenarios of novel ecosystems. It is designed to offer a práctica and theoretical base for the implementation of a cross-scenario, cross-ecosystem and cross-space assessment approach at local, regional and global levels.

Plant community ecology is one of the most general and abstract science fields of theoretical ecology and can be applied to link variations in species composition with variations in ecosystem function and variations in environmental conditions. Five drivers of change are recognized to affect a plant community, and can be assessed from large observational datasets. There are a variety of metrics commonly measured across communities and ecosystems that allow comparisons across systems. The following empirical criteria provide theoretical basis for examining if existing ecosystem resilience theory is general enough to predict change for any ecosystem type (biota, environmental conditions, disrupting agents).

Implications for Conservation and Management

The structure and functioning of the ecosystem is sensitive to changes in the environment. While there is some work on how environmental changes affect the plant communities within individual ecosystems, there are important gaps in our understanding of the patterns of change across ecosystems, the drivers of change, and the consequences for future ecosystem responses and management strategies. One integrative cross ecosystem assessment makes this clear, giving the foundation for successful management of plant community dynamics under varying conditions.

The results are used to inform conservation and management actions of plant communities and their services in the context of changing environments. Ecosystem monitoring should be based on regimes and indicators that relate to the resilience of the plant communities and their functionality, plus the support of adaptive measures at regional and landscape levels. Conservation prioritisation should not only be based on rarity and risk of extinction but also take into account ecological functions of existing communities, particularly in high latitude grasslands, temperate and boreal forests and fresh-water wetlands, in the context of changes in species composition that are caused by climate change and land use. Continued research and development are needed to answer the key questions and improve study techniques, especially on these ecosystems.

Knowledge Gaps and Future Research

There are a number of unanswered questions which deserve investigation for better understanding of plant community influences under future environmental conditions. Significant examples include complexity in plant diversity relationships due to biotic interaction, further research required on changes in beta diversity and processes driving community assembly, a mixed impact of increasing disturbance on diversity and community composition, relative stability or instability of plant functional diversity on ecosystem functioning, and the varying extent of facilitative effects relative to predictions.

New knowledge capacity would be greatly enhanced by taking into account temporal and spatial scale dependency; developing better methods for tipping point detection; developing modification of the species-flux relationship for system functioning; and adding fish, invertebrate, mammal assemblage traits to plant response parameters. Opportunities for synthesis across a wide range of data types, from historical and paleoecological, would enhance the field. In addition, new approaches to vegetation sensing, established methods for augmented reality vegetation visualization, and improved approaches to detecting habitat preparation by other species are worth highlighting. Further areas of meaningful research attention are enhanced understanding of spatially and temporally lagged responses, species-habitat suitability modelling under changing climates, interactions among multiple drivers of change and impacts on biodiversity–ecosystem functioning relationships. The provision of this information will help to create effective policies for conservation and management as part of an ongoing program of creating a lasting biophysical legacy.

Conclusion

The present study is a response to the growing demand for assessment of ecological conditions in both natural and anthropogenic environments and evaluation of plant communities in relation to the extrinsic and intrinsic environmental variables and stressors. The results obtained from the activities are used to create a comprehensive understanding of the reaction of plant communities to various drivers of environmental change, thus providing a perspective that includes both managed and natural ecosystems. Grassland, forest, and wetland patterns of species composition, ecosystem functioning, and service provision are documented and interpreted, and patterns in alpine/montane ecosystems are also documented and interpreted. Cross ecosystem comparisons reveal shifts in plant-community condition and richness, alteration of defining functional traits, loss of primary regulating functions, loss of habitat quality for animals, and variation in resilience. Climate change, land-use change, pollution, species invasion, and human activities, especially at local to regional scales, have a strong influence on the changing condition and structure of plant communities on different ecosystem types, but a few patterns are congruent across ecosystems and thereby provide critical information for future planning in the context of conservation.

An ecological-community synthesis of the resilience of ecosystems to environmental change is urgently needed. This synthesis should draw on the existing understanding of the structure of the ecosystem, which can inform change in ecosystem monitoring, and validated guidance for adaptive stewardship and management strategies that can reduce impacts from disturbance events and help ensure ecosystem condition, quality, and service provision are maintained over climate change.

Acknowledgement

The author expresses sincere gratitude to all those who contributed directly or indirectly to the preparation and completion of this study on the ecological assessment of plant communities under changing environmental conditions.

The author is especially thankful to the Department of Botany, Shri Sant Gadge Maharaj Mahavidyalaya, Loha, for providing academic support, encouragement, and a conducive environment for the preparation of this work.

The author also gratefully acknowledges the valuable contribution of researchers and scientific literature consulted during the study, which provided important insights into plant community ecology, environmental change, biodiversity, ecosystem functioning, resilience, remote sensing, and conservation management.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of thesis paper.

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