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Review on biodiversity, ecosystem services and genetically modified organisms

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ABSTRACT

Introduction. Understanding the relationship between ecosystem and diversity requires knowledge of how species interact with each other and how each is affected by the environment. It is useful to distinguish between the instantaneous effects of species richness on ecosystems and those which become deceptive on a longer time scale, described here as filter and founder effects. Biological diversity appears to enhance the resilience of desirable ecosystem states, which is required to secure the production of essential ecosystem services. Aim. The diversity of responses to environmental change among species contributing to the same ecosystem function, which we call response diversity, is critical to resilience. Response diversity is particularly important for ecosystem renewal and reorganization following change. Here we criticism the various roles that biodiversity, ecosystem services and genetically modified organisms play in terrestrial ecosystems with special emphasis on their contribution to productivity and diversity. Therefore, the aim of this review is summarizing of different articles and writing of the effects of one to the others, and the relation between biodiversity, ecosystem services and genetically modified organisms.

Review Article

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INTRODUCTION

The growing demand for food poses major challenges to humankind [1]. Genetically modified (GM) crops are subject to regulatory approval before entering the market [2]. Genetically modified (GM) crops have been commercially grown for 10 years [3]. The Millennium Ecosystem Assessment (MA) documented the dominant impacts of agriculture on terrestrial land and freshwater use, and the critical importance of agricultural landscapes in providing products for human sustenance, supporting wild species biodiversity and maintaining ecosystem services [4].

Epidemiological studies recommend that living close to the natural environment is associated with long-term health benefits including reduced death rates, reduced cardiovascular disease, and reduced psychiatric problems. The significance of biological diversity in maintaining such systems cannot be overemphasized [5]. Diversity of crops above ground as well as diversity of soil life below ground provided protection against the vagaries of weather, market swings, as well as outbreaks of diseases or insect pests [6].

In recent decades, the concept of ecosystem services (ES) has gained widespread attention as one fruitful approach for integrating into decision-making ecosystem-related values often heretofore dismissed as externalities [7]. Ecosystem services are functions provided by nature that improve and sustain human wellbeing [8]. In agro-ecosystems, biodiversity performs a variety of ecological services beyond the production of food, including recycling of nutrients, regulation of microclimate and local hydrological processes, suppression of undesirable organisms and detoxification of noxious chemicals [9]. Many ecosystem services are delivered by organisms that depend on habitats that are segregated spatially or temporally from the location where services are provided [8].

The majority of farmers in the developing world tend small plots in marginal environments, using indigenous agricultural methods. These diversified agro-ecosystems have emerged over centuries of biological evolution, and represent the experiences of farmers interacting with their environment without access to external inputs, capital, or scientific knowledge [10].

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Large-scale exploitation of wild animals and plants through fishing, hunting and logging often depends on augmentation through releases of translocated raised individuals. Such releases are performed worldwide in vast numbers [11]. For example, in the rice endosperm, the edible part of the rice grain, the micronutrients iron, folate, pro-vitamin A, and vitamin E are present only at minimal levels while in the rice leaf they are present in quantities which would be adequate if rice leaves were apt for human consumption. Unfortunately, large parts of the world's population survive on less than two dollars a day and hence can neither diversify their diets nor buy supplements [12].

The prime aim and justification of conservation research is to benefit biological diversity, whether through identifying patterns and mechanisms, quantifying changes, recognizing problems, or testing solutions. Many of the successes in conservation can be attributed to the successful translation of conservation science to conservation practice [13].

Individual organisms within a community may represent different species or different genetic variants within species. The birth, death and movement of individuals determine the dynamics of populations and communities, and therefore both genetic diversity within populations and species diversity within the community. Species diversity and genetic diversity have traditionally received independent treatment by community ecologists and population geneticists, respectively, despite repeated recognition in the literature over the past 30 years of potential connections between these two most fundamental levels of biodiversity [14].

Despite a worldwide biodiversity crisis and negative impacts of biodiversity loss on humanity, conservation is not as prominent in political agendas as some believe it should be. This is largely because most conservation strategies fail to incorporate the flow of benefits from ecosystems to people (ecosystem services). Yet, for conservation to gain greater prominence in political agendas, these schemes must demonstrate how conservation efforts can also meet human needs [15]. Therefore, in this review, I attempted to summarize the current condition, available evidence, and present information about biodiversity, ecosystem services and genetically modified organisms and their impacts on the existing environments.

GENETICALLY MODIFIED ORGANISMS

GMOs can be defined as organisms in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating or natural recombination, i.e. by being genetically modified (GM) or by recombinant DNA technology. The addition of foreign genes has often been used in plants to produce novel proteins that confer pest and disease tolerance and, more recently, to improve the chemical profile of the processed product, e.g. vegetable oils. In the European Union (EU) and other regions, the use of this technology, the consequent release of GMOs in the environment and the marketing of GMO-derived food products are strictly regulated [16].

Types of GMO testing

GM products contain an additional trait encoded by an introduced gene(s), which generally produce an additional protein(s) that confers the trait of interest. Raw material (e.g. grains) and processed products (e.g. foods) derived from GM crops might thus be identified by testing for the presence of introduced DNA, or by detecting expressed novel proteins encoded by the genetic material. Both qualitative (i.e. those that give a yes/no answer) and quantitative methods are available. Laboratories carrying out these assays must be proficient in performing them [17].

Testing for (detection of) GMOs

Testing for (detection of) GMOs may serve several purposes. Qualitative testing may be used to discriminate between authorized and unauthorized material or use of material, to identify safe or potentially unsafe material, or for certification of purity of identity preserved material. Quantitative testing may be used to control for compliance with legal (e.g. for labeling) or contractually agreed thresholds (e.g. with respect to botanical impurity). Testing may also play a role in the safety assessment and risk management of GMOs by providing a means of tracing and if necessary retracting the GMO material, by providing data from characterization of the GMO itself [18].

The test report therefore must provide information not only about the test result but also about the uncertainties and limitations associated with the test result. This information must be presented in a form that is perceived and interpreted correctly by the stakeholder. The responsibilities of the analysts include: 1) appropriate choice of testing method, including method validation status; 2) identification of potential sources of error in reporting and translation of results; and 3) communication with the stakeholders *a priori*, explaining what the analyst can provide, and *a posteriori*, explaining what the results mean including relevant limitations. Most testing is not performed by the same people who sample the material that is subject to testing, and sampling is not covered in the present paper. Because the sampling error may be much larger than the analytical measurement uncertainty or error, the interested reader is referred to for more information on sampling [19].

ECOSYSTEM SERVICES AND BIODIVERSITY

Human impacts on the environment are intensifying, raising vexing questions of how best to allocate the limited resources available for biodiversity conservation. Which creatures and places most deserve attention? Which should we ignore, potentially accepting their extinction? The answer to this dilemma depends on one's objectives. To motivate action, conservationists often mix diverse ethical and practical objectives, hoping they will reinforce each other. But attention given to one goal may instead diminish the prospects for achieving others [20].

Ecosystem Services

Relationships between ecosystem services and human well-being are poorly understood [21]. Most research related to ecosystem services focuses on direct drivers, such as land use change or invasive species. Yet, effective management requires more attention to indirect drivers such as demographic, economic, sociopolitical, and cultural factors. Lack of knowledge of trends in human reliance on ecosystem services also posed serious constraint in the MA analysis. Lack of appreciation of humans dependence on natural ecosystems represents but one of a complex of interacting factors responsible for today's array of anthropogenic disruptions of the biosphere. Yet, it clearly represents a major hindrance to the formulation and implementation of policy designed to safeguard earth's life-support systems [22].

Moreover, lack of understanding of the relations between ecosystem services and human well-being traces ultimately to a failure of the scientific community to generate, synthesize, and effectively convey the necessary information to the public. In fact, the benefits provided by natural ecosystems are both widely recognized and poorly understood. Consequently, it is vital to understand the relationships between ecosystem services and human well-being as well as their changes following economic development, including: (*i*) the correlations between human well-being yielded from ecosystem services and economic growth; (*ii*) the dynamics of the dependence of humans on different types of ecosystem services; and (*iii*) the effects of ecosystems and biodiversity on human well-being yielded from ecosystem services [23].

An assessment of the capacity of ecosystem services to benefit a given community requires identification and quantification of human-related benefits, costs, and the availability of alternatives to meet needs [15].

Ecosystem Diversity

Ecosystems are complex, adaptive systems characterized by historical dependency, non-linear dynamics, and multiple basins of attraction. We are part of ecosystems and alter their dynamics through activities that change the atmosphere and climate, land surface, and waters. In the future, we are likely to face different, more variable environments, and there will be greater uncertainty about how ecosystems will respond to the inevitable increases in levels of use. At the same time, our activities have already reduced the capacity of ecosystems to cope with disturbance and change. Here we highlight the often neglected but essential role of diversity within functional groups in the adaptive capacity of ecosystems [24].

Ecosystem resilience may be an essential factor underlying the sustained production of natural resources and ecosystem services in complex systems faced with uncertainty and surprise. Ecosystem resilience is defined as the amount of disturbance a system can absorb and still remain within the same state or domain of attraction [25]. Resilience also encompasses the ability of an ecosystem subject to disturbance and change to reorganize and renew itself. The definition includes the degree to which the system is capable of self-organization (versus a lack of organization, or organization forced by external factors), and how much it expresses a capacity for learning and adaptation [26].

Genetic diversity

Genetic diversity, defined here as any measure that quantifies the magnitude of genetic variability within a population, is a fundamental source of biodiversity. For more than 80 years, the study of genetic diversity has principally been the domain of evolutionary biologists [27].

The pioneering work of the modern evolutionary synthesis provided the theoretical and empirical foundation for the study of genetic diversity, including the derivation of new standard quantitative metrics of genetic diversity such as heritability and genetic variance. Since the modern synthesis, interest in genetic diversity has focused on its origin and maintenance, its role in the evolution of sexual reproduction and how the level and types of genetic variance affect the rate of evolutionary change within populations [28].

Species-individual diversity

Species diversity and genetic diversity can be defined, measured or manipulated in a number of different ways. Species diversity is most often measured as species richness, the number of species in a given locality. In studies that experimentally manipulate species diversity (review, it is also most often species richness that is varied among treatments. Several indices of species diversity incorporate information about the relative abundances of species in a locality, with higher diversity indicated by a more even distribution of abundance among species higher 'evenness' [14].

Functional diversity

Use of the term 'functional diversity' has grown exponentially over the last decade and in 2003-2005 it give the idea in the title, abstract or keywords of 238 articles. These include studies of marine, freshwater and terrestrial ecosystems, and span a wide range of taxa from bacteria to bats. Functional diversity generally involves understanding communities and ecosystems based on what organisms do, rather than on their evolutionary history. This is a very general definition for functional diversity and an enormous amount of ecological research is relevant. For example, if 'what organisms do' is interpreted as the organisms' phenotype (i.e. a phenotypic trait) then functional diversity equates with phenotypic diversity and the majority of ecological research has touched on this subject [29].

CONCLUSION AND RECOMMENDATIONS

In the area of biodiversity, ecosystem services, genetically modified organisms, sampling will mainly be an issue with respect to testing of raw materials and ingredients where most problems of inhomogeneity will exist. At the same time as there will be few problems of ecosystems diversity to the importing genetically modified organisms with processed foods i.e. retail foods, there will be enormous difficulties in developing validated methods of analysis robust enough to cover the full range of food types. To sustain biological and ecosystems richness in the country, it should be build and form regulatory body to be more practical to carry out sampling at the factory rather than at retail level. To date, there have been no attempts to study the problems of homogeneity of consignments of non-GMO and clearly this work will need to be undertaken to develop sampling plans. For this purpose the experience of ecosystems services and biodiversity diversity is equivalent areas to be valuable in developing country. Based on the above information the following recommendations should be forwarded:

- Current natural resource management seldom takes the ecosystem functions performed by organisms that move between systems into consideration.
- There is a need for generic protection goals that are independent of the agricultural technology used; what constitutes environmental harm should not be defined by the technology causing the harm.
- Sustainable development requires the reconciliation of demands for biodiversity conservation and increased agricultural production.
- The adoption of herbicide-resistant crops has reduced crop rotation and favored weed management that is solely based on the use of herbicides.

DECLARATIONS

Authors' contributions

MB, AK and HD conceived the review, coordinated the overall activity and drafted the manuscript.

Availability of data and materials

Data will be made available up on request of the primary author

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Consent to publish

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Competing interests

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