

Synergies and trade-offs of biotechnology and climate smart agriculture: review

Abstract

The unwise utilization of any technology has negative impacts on either economy, environmental sustainability, socio-culture, or in combinations. Many scholars argue that biotechnology is a cause for biodiversity loss (reduces genetic diversity), causes deforestation due to genetically modified crops, human health problem (cancer), and disrupting the integrity of natural biota. Equally, others argue that biotechnology is a fortunate to conserve biodiversity via gene bank, improve crop yield, reduces use of pesticides, improves human health (pharmaceutical value), and reduces wastes in the environment. Whereas, climate-smart agriculture aims to enhance food security via increased productivity and income, resilience and adaptive capacity to climate change, and reduce greenhouse gas emissions. To achieve this goal, it is better to use biotechnology in a very limited amount to reduce the tradeoffs between them.

Keywords: biodiversity, economy, emissions, resilience

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Introduction

The synergic effects of industrialization, fast population growth, climate change, and agricultural land expansion has been severely affecting biodiversity, social stability (bond), food security and deaths in different parts of the world. Unfortunately, projections show that these problems will be more severe in future years.¹ Consequently, Food and Agriculture Organization of the United Nations developed an approach called climate-smart agriculture. It is an approach to help guide actions to transform and reorient agricultural systems to effectively and sustainably support development and food security under a changing climate.² This approach has three pillars, namely: sustainably increasing food security, building resilience and adapting to climate change, and reducing greenhouse gas emissions. However, it is difficult to achieve all pillars equally at the same time, as a result of which significant environmental and social crises are coming from different development projects.

Biotechnology has both positive and negative impacts on the achievement of climate-smart agriculture goals. For instance, it causes biodiversity loss by modifying the genetic makeup of organisms (genetic erosion), improved varieties are productive only for first round and fail later, new invasive species appear in soils where improved varieties were grown. Moreover, improved varieties are only big in size but not delicious to eat and cause cancer in human body.³ Conversely, biotechnology helps endangered and threatened species to survive the changing climate by modifying the DNA (deoxyribonucleic acid) of the organisms. Besides, it increases the crop yield by developing stress tolerant variety, which in other words, enhance resilience of farmers to negative impacts of climate change. And it also improves the nutrient and water uptake efficiency of crops, which reduces depletion of nutrients among others. Detail arguments will be described in the following different sessions.

Definitions and concepts

Biotechnology is defined as the exploitation of biological processes for industrial and other purposes, especially the genetic

manipulation of microorganisms to produce antibiotics, hormones, and others (Dictionary definition). It is mostly related with genetical modification (GM) which is the process of enabling individual genes that make up a DNA (deoxyribonucleic acid) code to be modified to express or suppress important traits, and the organisms obtained by such a way are called genetically modified organisms or GMO.⁴ Whereas, biodiversity is the variability among living organisms from all ecosystems and the ecological complexes of which they are part, which is diversity within species, between species and of ecosystems.⁵

Impacts of biotechnology on biodiversity

Biodiversity of the world has been decreasing at alarming rate due to the synergic effects of industrialization, fast population growth, climate change, and agricultural land expansion. Industrialization is a cause for biodiversity loss either by converting the natural habitats to settlements or identifying new approaches to utilize resources which were not used directly before industrialization. Agricultural land expansion is caused by fast population growth to obtain food, which converts forests and grasslands to crop lands(monoculture). Likewise, climate change has been significantly affecting biodiversity due to increased temperature in which only few species are favored and invading others. Any ecosystem is not the same as it was before industrialization. Over the past 50 years, more than half of the original area of many types of grasslands and forests has been converted into farmland.⁵

Since genetically modified varieties need open environment to use their maximum potential, they cause further deforestation, which result in severe soil erosion. Grau et al.,⁶ concluded that the initial deforestation in northwest Argentina was associated with black bean cultivation during the 1970s. The introduction of genetically modified (GM) soybean in 1997 stimulated a further increase in deforestation, which has been mirrored in other Latin American countries. The demand for food is projected to increase, and a further 10-20% of grassland and forests are expected to be converted to agriculture by 2050.¹

Native species are either endemic or indigenous to a given country or location which are the bases for biodiversity. Native species are adaptive to the given environmental conditions and live through natural balance. However, biotechnology and its outputs disrupt the natural and biological control resources.⁷ For instance, GMOs result in promotion of secondary pests, impact on non-target arthropods, soil biota, and biogeochemical cycles.

Invasive alien species cause species endangerment and extinction.⁸ GM can have the ability to create changes that enhance the ability of an organism to become invasive. While GM transfers only short sequences of DNA relative to the entire genome of a plant or animal, the resulting phenotype, which includes the transgenic trait and possibly other accompanying changes, can produce an organism novel to the existing network of ecological relationships, and can therefore be potentially invasive.⁹ All in all, only few (alien invasive species) will be favored and the natural biodiversity will be severely affected due to biotechnology.

Lövei¹⁰ recommended that when introducing new technologies like GMOs, their potential impact on ecosystem services must be tested. Such testing is even more important in tropical countries, where agricultural producers often depend on ecosystem services more closely than farmers in the developed countries. As GM crops will be grown outdoors, in contact with surrounding ecosystems, and they certainly have the potential to substantially modify current agricultural practices.¹¹ Another example of species affected by *Bacillus thuringiensis* toxin (Bt) maize is *Apis mellifera* (honey bee) which is a beneficial insect highly involved in pollination and honey production.^{12–15} Malone et al.,¹⁶ found that at high doses, serine protease inhibitors inhibit bee gut proteases, which may result in reduced adult bee longevity. This therefore implies that GMO plant material also affects the natural food chains and food-webs.

Impact of biotechnology on agricultural productivity

Application of genetic technology in agriculture can have negative and positive impacts on the natural environment's flora, fauna, soils, and others.¹⁷ Due to the use of genetically modified crops, some weeds can be changed and develop resistance to management measures,⁷ and these crops require an increased use of pesticides.^{8,18} Conversely, some scholars argue that biotechnology allows for the transfer of only one or a few desirable genes, thereby permitting scientists to develop crops with specific beneficial traits and reduce undesirable traits. For instance, as a substitute for fishing from natural stocks, aquaculture has improved protein levels in developing countries and reduced pressure on native species, particularly salmon. However, coastal aquaculture is already causing ecological damage by spreading fish diseases, modifying habitats, causing nutrient pollution, and changing ecosystems through the escape of exotic farmed fish.¹⁹

Impacts of biotechnology environmental health

Environmental biotechnology is used in waste treatment and pollution prevention. This is a solution for increasing solid and liquid wastes due to industrialization and discharge rate by increasing population. In this case nutrients are added to wastes to stimulate microbial activity to degrade wastes, the method is called bioremediation. Besides, a harmless strain of *Escherichia coli* bacteria is used to produce insulin using biotechnology. The environmental impact of genetic engineering on ecosystem services will have to be examined thoroughly.¹⁷ Herbicide and pest resistant genetically

modified crops might lead to an increase in herbicide application.^{20,21} and that toxins produced may enter and disturb the food web and thus affecting non-targeted organisms.²²

The potential risk on the food web is most likely to have huge impacts on animal species, ecosystems and humans mostly because these effects may be irreversible.²³ Besides, transgenes (transgenic modification) might escape into the wild populations and transform the natural ecosystem.²³ Transfer of transgenic DNA has been regarded as an infringement of the integrity of organisms and an interference with the natural order of nature.⁸ Unintended hybrid strains of weeds and other plants can develop resistance to these herbicides through cross-pollination.^{24,25} The impact will be out of control,²⁶ for example, engineered sugar beet ended up having the genes completely resistant to herbicide.^{18,27}

Conclusion

Biotechnology and climate-smart agriculture have better synergic effects in the development of the countries. Because, biotechnology provides genetically modified crops that have better yield, reduces use of pesticides, conserve threatened and endangered species in gene bank, improves human health via pharmaceutical value, and enhance environmental health via bioremediation in which wastes are degraded. On the other hands, they have tradeoffs since biotechnology modifies naturally existing biota, and causes exploitation of previously untapped resources, enhances alien invasive species, genetically modified crops cause cancer in human, increases deforestation and land degradation. In general, except environmental biotechnology, it's better to reduce the application of biotechnology to achieve the goals of climate-smart agriculture.

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Conflicts of interest

The author declares there are no conflicts of interest.

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