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MUTUALISM BETWEEN BEES AND PLANT BIODIVERSITY.

John Oloo,

Department of Natural Resources Management, School of Spatial Planning and Natural Resource Management, Jaramogi Oginga Odinga University of Science and Technology,

https://orcid.org/0009-0006-3408-9463

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ABSTRACT

Purpose: Biodiversity is an attribute of an area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans while bees (Apidae) are the most important group of pollinators. The purpose of this research was to investigate the causes of decline of bees' population in the environment vide syntheses of existing scholarly research in answering: (i) what are the threats facing bees and (ii) how can the threats facing bees be addressed to reverse the decline rate.

Methodology: The methodology adopted was systematic literature review on the subject matter.

Findings: Findings are that, the threats include: changes in land use, loss and fragmentation of habitats, introduction of exotic organisms, modern agricultural practices, pesticides, crop monoculture, agrochemicals, biotic and abiotic stressors caused by human activities, global warming and climate change. The various strategies that can be used to revert the trend include: investment in restoration and management of a diversity of pollinators and their habitats, introduction of new tillage (reduced, minimum, and non-tillage), minimal use of agrochemicals and timing of their applications, conservation or introduction of hedge grows and their constituent weedy plants, encouraging blooming weeds or establishing diverse plantings, and incorporating structural diversities.

Unique Contribution to theory, practice and policy: In conclusion, people are putting more strain on the world than before, consuming and using more things than before, and risk upsetting ecological equilibrium and wiping off species. Healthy ecosystems purify our waters, cleanse our air, manage our soil, control our climates, reuse nutrients, and provide us with food. They provide raw materials to the pharmaceutical industry and other industries and the demand for animal pollination services is rising at the same time that pollinator abundance and diversity are declining. I recommend that environmental education and civic awareness should be used so that individuals can recognize the difference between the essential requirements and limited natural resources available.

Keywords: *Biodiversity, Pollinators, Conservation*

Introduction

Biodiversity is an attribute of an area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans. Biodiversity can be measured in terms of genetic diversity and the identity and number of different types of species, assemblages of species, biotic communities, and biotic processes, and the amount (e.g., abundance, biomass, cover, rate) and structure of each. It can be observed and measured at any spatial scale ranging from microsites and habitat patches to the entire biosphere (DeLong, 1996). Biodiversity is not distributed evenly across the planet but shows a rather uneven distribution, certain ecosystems and regions contain far more species than others. Tropical rain forests, coral reefs, the deep sea, and large tropical lakes appear to be the most species rich ecosystems on the planet (WCMC 1992; Heywood 1995; Levin 2001). For most groups of terrestrial plants and animals, species diversity is lowest near the poles and increases toward the tropics, reaching its peak in tropical rain forests. These forests, occupying only 6 percent of the earth's land surface, are believed to contain more than half the species on earth.

Biodiversity, therefore, is usually considered at three hierarchical levels i.e. *Genetic*, *Species* and *Community and Ecosystem* levels.

Genetic diversity

Genetic diversity refers to any variation in the nucleotides, genes, chromosomes, or whole genomes of organisms. This is the "fundamental currency of diversity" (Williams and Humphries, 1996) and the basis for all other organismal diversity

Genetic diversity is the sum total of genetic information, contained in the genes of

individuals of plants, animals and microorganisms that inhabit the earth.

It is needed by any species in order to maintain reproductive vitality, resistance to

disease and the ability to adapt to changing conditions.

It enables a population to adapt to its environment and to respond to natural selection.

The amount of genetic variation is the basis of speciation.

Genetic diversity within a species often increases with environmental variability.

Such genetic variability has made it possible to produce new breed of crops plants and domestic animals, and in the world allowed species to adapt to changing conditions.

Species Diversity

A group of organisms genetically so similar, that they can interbreed and produce fertile off-springs is called a species. The species diversity is usually measured in terms of the total number

of species within discrete geographical boundaries. Species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups. Species are distinct units of diversity each playing a specific role in the ecosystem. In nature, both the number and kind of species, as well as the number of individuals per species vary, leading to greater diversity.

Community-level diversity:

It is defined by the species that occupy a particular locality and the interactions between them. It represents the collective response of species to different environmental conditions. Biological communities such as deserts, grasslands, wetlands, and forest support the continuity of proper ecosystem functioning by providing ecological beneficial services to people (Ghilarov and Timonin, 1972)

Importance of Biodiversity (BD)

(Morton and Hill, 2014) assert that biodiversity benefits us for a multitude of reasons. Many individuals feel that biodiversity has inherent worth, which means that every species has significance and a right to live whether or not something benefits humans. In their biodiversity book, they underline five important values that individuals put on biodiversity

1. Biodiversity helps us in many ways economically as it provides raw materials for consumption and industry. Biodiversity is vital to the livelihoods of farmers, fishermen, and forest workers.

2. Because it supplies oxygen, clean air and water, plant pollination, insect control, wastewater treatment, and a number of other functions, biodiversity is essential for ecosystems to function properly.

3. Many recreational activities including as bird viewing, hiking, camping, and fishing, rely on our unique biodiversity. The tourism business in our country is strongly reliant on biodiversity.

4. Through expressions of identity, morality, and aesthetic appreciation, Australian culture is inextricably linked to biodiversity. Indigenous Australians have deep religious convictions about plants and animals, which has ultimately led to deep links with biodiversity and a sense of social responsibility for it.

5. Biodiversity is a vast repository of biological information that enhances our understanding of nature and its origins.

Nature's diversity, biosphere, richness, and life on Earth are all maintained via biodiversity. It is really beneficial to the environment. Life on Earth would perish if it didn't exist. Biodiversity is often seen to be helpful and desirable since it contributes to community stability and higher output (Minni, 2022)

Five ways biodiversity supports economies and enhances wellbeing (Quinney, 2020)

The importance of biodiversity for human health and food security

Biodiversity is the foundation of global nutrition and food security. Regardless of the fact that millions of species collaborate to offer us with a diverse range of vegetables, fruits, and animal foods that are important for a healthy, well-balanced diet, they are now becoming increasingly threatened.

Biodiversity assists fight diseases

Human health has been related to higher levels of biodiversity. For starters, plants are essential for the creation of medications. For example, rainforest plants are used in 25% of modern medications, whereas natural or synthetic chemicals inspired by nature are used in 70% of cancer therapies. This implies we lose out on a potential new medication every time a species goes extinct.

Biodiversity helps for business

According to the World Economic Forum's annual Nature Risk Rising Report, more than half of the world's GDP ($44 trillion) is reliant on nature. The rapid biodiversity loss has put many enterprises in jeopardy. Natural-materials based pharmaceuticals are expected to generate $75 billion in annual revenue, while natural marvels like coral reefs are crucial for food and tourism.

Biodiversity provides livelihoods

Every year, ecological systems are valued $125 trillion to humanity. Three out of every four jobs need the usage of water, and the agriculture industry employs more than 60% of the world's working poor. Forests provide a source of income for about 1.6 billion people in the Global South.

Biodiversity protects us

We are able to exist on this planet because of biodiversity. Bio diverse ecosystems protect us from natural calamities like floods and storms while also purifying our systems and renewing our soils. Healthy biodiversity provides natural services such as water resource preservation, soil development and protection, nutrient storage and recycling, pollutant breakdown and absorption, contribution to climatic stability, ecosystem management, and restoration from unexpected events (Shah, 2014). Food, medicinal treatment, decorative flora, future resources, gene diversity, species variety, and ecological diversity are all given. It offers societal benefits including research, education, and monitoring, as well as recreational and tourism possibilities and cultural values. In healthcare coverage, traditional medicine remains to play an essential role. Traditional medicines are used by 60% of the world's population, and they are widely integrated into public health services in many nations. Medicinal plants are the most often used therapeutic option in both conventional and complementary medicine all over the world. Plants are gathered from both wild and cultivated populations for medicinal purposes. In addition to subsistence, many communities rely on natural goods derived from ecosystem for medicinal and cultural purposes (WHO, 2015).

Sustainable agriculture further enhances biodiversity in the region by providing a natural and healthy habitat for a range of species to thrive in (Padhy, 2015).

Loss of Biodiversity (BD).

Healthy ecosystems are essential to human cultures. Fish, meat, crops, timber, and fibers such as cotton and silk are among the items consumed by people. Living organisms govern the environments on which crops rely. Trees and other plants take in carbon and release oxygen through photosynthesis. They are removing around 27% of what human industry and agriculture emits in the process (The Economist, 2021).Predicting and managing the effects of global change on species and ecosystems is a huge adjustment for ecology. Many species' phenology is changing as a result of climate change across the planet. Recent reductions in farmland biodiversity, mostly due to agricultural intensification, pose a danger to rural cultural values. Multiple environmental forces, such as temperature change and water color, will pose a hazard to aquatic systems in the future. Significant evidence has developed in recent years indicating arctic and alpine landscapes are undergoing dramatic changes in plant community structure (Lund University, 2021). In their daily lives, people rely on biodiversity. People's health is eventually reliant on ecosystems products and services such as clean water, food, and fuel, which are all essential for human health and productive lifestyles. Biodiversity loss can have major direct health consequences for humans if ecosystem services are no longer able to meet social needs. Changing ecosystem services have an indirect effect on livelihoods, earnings, local movement of people, and political unrest in rare situations (WHO, 2015).Climate change, global warming, increased insect pest and disease infestation in crops, farmers' exposure to continuous pesticide usage, commodity price volatility, and crop losses due to natural disasters including drought, floods, and cyclones are all harming farmers' mental health. (Padhy et al, 2020).

Bhavana Gupta (2024) asserts that factors causing loss of biodiversity are:

(i) Loss of Habitat

Destruction of habitats due to clearing of forests and grasslands for agricultural lands, pastures, settlement areas or project development lead to loss of habitat. These factors are responsible for the disappearance of thousands of species. According to the world Health Organisation (WHO) estimates, about 80% of the population of developing countries relies on traditional medicines, mostly drugs from plants. In order to meet the demand, about 86% of plant collection involves destructive harvesting. Many plants become endangered, besides loss and degradation of natural habitats take place due to overharvesting.

The wetlands, mangroves and estuaries with rich biodiversity are under threat. They are destroyed, as if they have no value. For example estuarine ecosystem in Adyar, Chennai has disappeared posing a major treat to nearly 170 species of birds, many of which nest and breed there. Tropical

forests disappear at the rate of 0.6% per year in our country. Marine biodiversity is also threatened by human intervention.

The wetlands in India are distributed in different geographical regions. Most of the wetlands in India are linked with major river systems. India has 27403 wetlands covering 4.1 million. Of these, 2,175 are natural and the rest are manmade. Wetlands occupy 18.4 of the area of our country of which 70% are under rice cultivation. In India, out of an estimated 4.1 million ha of wetlands, 1.5 mha are natural and 2.6 mha are man-made. Wetlands provide food and shelter for mammals and birds.

Poaching of wild life

The illegal commercial hunting is called poaching. There are two types of hunting subsistence hunting (killing animals for food) and sport hunting (killing animals to sell their meat, fur, horns, tusks etc.)

Man-Animal conflicts

Sometimes, wild animals threaten human beings. This leads to conflict between wild life and man. For example elephant in Sambalpur, Orissa killed 195 humans in 5 years. The villagers killed 98 elephants in retaliation and injured 30 elephants. According to Bhatnagar (2008) and Schlossberg (2010), the various threats are human population, habitat loss, invasive alien species, climate change, pollution, eutrophication, overfishing, soil erosion, soil degradation, poverty and loss of green forest. Bees belonging to the family (Apidae) are the most important group of pollinators, and the vast majority are represented by wild species (~20 000 species) [4].

Question1. What are the threats that bees face?

Agriculture poses many threats to insect pollinators such as changes in land use, loss and fragmentation of habitat, introduction of exotic organisms, modern agricultural practices, and pesticide use. Removal of weeds that provide forage for pollinators is a major factor in the decline of native pollinators in agro ecosystems (Richards 2001; Steffan-Dewenter et al., 2005). Several features associated with modern agriculture make farms poor habitat for wild bees and other pollinators, and many agricultural practices impact directly or indirectly pollinator populations (Kremen et al. 2002). Agricultural intensification has led to a more homogeneous landscape characterized by large weed-free fields and fewer non cultivated habitats. Habitat loss and degradation, e.g., loss of complex landscape structures between farmland and adjacent ecosystems, as well as the increased use of agrochemicals, have been linked to the reduction in beneficial arthropod species richness in agricultural landscapes (Kevan 1999)

Crop monocultures sacrifice floral diversity and, consequently, diversity of pollinating insects, over large areas. A large body of research shows that cultivated fields surrounded by simple habitats (i.e., other monocultures) have significantly fewer bees than crops surrounded by

uncultivated land, and the number of bumblebees on crops increases with proximity to natural habitats (Ockinger and Smith 2007). The conversion of land to agriculture results in a net loss of wild vegetation to support pollinators reducing nesting sites and less-varied microhabitats for egg laying and larval development. In this regard, the loss of hedgerow habitats, which provide floral resources and nesting sites for wild bees at the margins of cultivated fields is an undesirable trend associated with industrial agriculture (New, 2005).

Alarmingly, many wild bee populations are declining due to the impact of different biotic and abiotic stressors caused by human activities that act alone or in combination, such as pesticides, invasive species, pathogens, intensive land-use, and climate change (Dicks, 2021). In particular, agricultural intensification appears to negatively impact on wild bee communities Ragen &Wagner, (2021) In fact, overall biodiversity typically decreases with increasing land-use intensity Newbold, (2014), which directly or indirectly leads to loss of floral diversity and nesting sites Thomson, 2016. Floral diversity, abundance, and community composition correlate with the abundance and diversity of wild bee species Abretcht, (2020) through food availability Kaluza, (2018), nutritional quality or content. Bees thrive in environments where plant species diversity is high Lichtenberg, (2017).

Question 2. Which strategies can man employ to reduce the current declining numbers of bees?

Investment in the restoration and management of a diversity of pollinators and their habitats in croplands are of key importance for the stability of the yield of food crops, especially when considering that 35 % of global production comes from crops (at least 800 cultivated plants) that depend on animal pollination (Klein et al. 2007 and Gallai et al. 2009). Crop rotations affect weed seed-banks because weed control measures change with successive crops thus influencing weed species composition abundance. In the few studies, where rotation effects on weeds have been examined without herbicides as a confounding factor, rotation by itself led to reduced weed populations, especially where a small grain was included in the rotation. However, where crops are rotated, weed communities are more diverse than where crops are grown in monoculture, which again creates more favorable habitat and food conditions for pollinators (Ball 1992). The operational principle at work here is density versus diversity, as rotations tend to reduce weed density but enhance weed species diversity.

The introduction of new tillage practices (reduced, minimum, or non-tillage) commonly causes changes in the composition and abundance of weed species present in cropping systems. In arable crops such as soybean and maize weed, population shifts were observed when conventional tillage systems were changed to non-tillage (Ball and Miller 1990). Annual grass populations usually increase in non-tillage systems (Wrucke and Arnold 1985) whereas decreased populations of annual dicotyledonous weeds have been associated with non-tillage, which in turn may reduce

floral resources for pollinators. On the other hand, tillage practices that create special soil cover conditions influence pollinator abundance as shown in a survey of 25 squash and pumpkin farms in West Virginia and Maryland. Researchers found that squash bee density was three times higher in no-tillage farms than in tilled farms. Many small farmers that leave residues on soil or practice mulching may be inadvertently encouraging wild bees (Shuler et al. 2005). Extensive tillage practices that inhibit or destroy nests should be avoided. Often times, diverse farms with a variety of landscape features including patches of bare soil, piles, or hedgerows of stone and clump-forming grasses can provide ample nest habitat for wild bees (Steffan-Dewenter 2002).

The use of herbicide for weed removal affects pollinators by reducing the availability of nectar plants. It is well known that herbicide spraying and mechanical weed control in alfalfa fields reduce nectar The magnitude of the effect for each species is related to the length of its seasonal flight period. Many bees have a flight period that extends beyond the availability of alfalfa flowers. Some of these bee populations show massive declines due to the lack of suitable nesting sites and alternative food plants (Benedek 1996). This situation is also common in other agroecosystems where flowering weeds are eliminated especially in periods where the main crops are not flowering. By destroying larval food sources and safe sites, herbicides can also severely affect pollinator populations (Kevan et al. 1997).

In intensive agricultural areas where weeds are not tolerated within large fields, a priority should be to conserve or reinforce the hedgerows and their constituent weedy plants such as nettles, wild umbelliferae, comfrey, wild clovers, etc., as well as herbaceous plants, especially the more specialist long-corolla perennials that tend to have more nectar than annuals (Corbet 1995). In addition to pollen and nectar for adults and food plants for larvae, hedgerows provide shelter and nesting sites for many pollinators (Fig. 1). Many hedgerows supply the substrates that provide nesting sites for various pollinator species. Such substrates include undisturbed areas and bare ground, dry branches or logs, or sandy or earth bank (Willmer 2011). Many crops grown near fragments of native forests get significant pollination benefits, as shown in grapefruit crops closed to subtropical forests in Argentina, where Chacoff and Aizen (2006) found greater pollinator diversity close to the margins.

Effective weed suppressive intercropping systems are those that capture a greater share of the available resources (nutrients, water, sunlight, etc.) that otherwise weeds would utilize. Many studies have shown that a variety of intercrops intercept more light, capture greater quantities of macronutrients and water, and produced higher yields while containing lower weed densities than corresponding monocultures. Although these systems are well suited to small-scale labor intensive

farming systems, certain crop mixtures (i.e., maizesoybean strip-cropping or mixtures of small grains with red clover) are compatible with farm machinery and thus can be adapted in large-scale systems (Liebman and Davis 2000).

One of the challenges that bees face in agricultural landscapes is a lack of season-long food sources (Bohart 1972). Large monocultures of bee-pollinated crops like almond, canola, or watermelon, may provide a few weeks of abundant food, but a lack of within field or adjacent wild plants blooming before and after the main crop blooms can result in a decline of healthy pollinator numbers (Goulson 2003). As it has been explored in this paper, encouraging blooming weeds or establishing diverse plantings can provide the floral diversity to support resident pollinators (Fig. 2). Bee diversity is often maximized in landscapes where 15 or more flowering plant species are present, as different bees have different flower preferences, this season-long food supply is especially critical early and late in the year (Willmer 2011). Native bees remain dormant throughout the winter and often need immediate food sources upon emergence in the spring. Bees that over-winter as adults, like bumble bees, often need late-season nectar sources to build up their energy reserves for the long winter. Similarly, honeybees spend winter inside the hive living off honey from nectar they collected over the summer months. Without enough honey, honeybees can starve over the winter resulting in the entire hive dying off.

Fig. 1 Hedgerows enriched with native plants that provide a flowering succession throughout the year

(Adopted from INRA and Springer-Verlag, France 2012)

Fig. 2 Corridor of flowering shrubs that cuts across a blueberry field in Chile

(Adopted from INRA and Springer-Verlag, France 2012)

Garden habitats with more plant species support greater pollinator diversity (Majewska and Altizer 2020) because each pollinator species visits a subset of flower species and because attractiveness varies widely across plant taxa (Garbuzov and Ratnieks 2015). Gardens with higher floral diversity are also generally preferred by the public, thanks to their variation in flower color, size, and shape (Lindemann-Matthies and Bose 2007).

Incorporating structural (physical) diversity, including bare soil and woody plants, provides nesting habitat and food resources for many pollinator species (MacIvor et al. 2014, Fortel et al. 2016). This feature of pollinator gardens is also in line with public preferences, as survey participants' imagined ideal landscapes include substantial structural diversity (Lindemann-Matthies and Bose 2007).

Though non-native plants can support many native pollinators (Shapiro 2002), some specialist pollinators rely exclusively on native plants (Burghardt et al. 2009), which are also less likely to act invasively, offer inaccessible rewards (Corbet et al. 2001), or act as evolutionary traps whereby native pollinators are attracted to the plant but perform poorly on it (Nakajima et al. 2013). For landholders, native plants may also come with no increase to costs, as suggested by the finding

that in cities, household income predicts exotic species diversity significantly better than native species diversity (Chamberlain et al. 2020).

Effective pollinator gardening does not require wholesale conversion of all outdoor space to flowers. Grass lawns, which are widely valued as safe spaces for leisure and play (Larson et al. 2009), can be mowed less frequently to minimize disturbance and allow weeds to bloom, which attracts more insects (Lerman et al. 2018). Maintaining taller, semi-natural meadow areas alongside conventional low-cut lawns can also be appealing to the public (Fischer et al. 2020) and can substantially reduce maintenance costs (Watson et al. 2020).

Conclusion

Biodiversity indicates the diversity of all living organisms, including plant, animal and bacteria, the genetic data and ecosystems they produce. People are putting more strain on the world than before, consuming and using more things than before, and risk upsetting ecological equilibrium and wiping off species. Healthy ecosystems purify our waters, cleanse our air, manage our soil, control our climates, reuse nutrients, and provide us with food. They provide raw materials to the pharmaceutical industry and other industries. They are the foundation of all civilizations and the source of our economy's vitality (Wilson et al., 2010). It is required to strengthen resilience and adaptive capacity to climate hazards and natural disasters in all countries (Envision2030, Goal 13). Researchers have reported that the area devoted to pollinator dependent crops has increased faster than that of nondependent crops in both the developed and developing worlds. Therefore, the demand for animal pollination services is rising at the same time that pollinator abundance and diversity are declining. Researchers have also found a trend of lower growth rate in yield in crops that depend highly on pollinators compared with those with low or none dependence. All these results could be interpreted as an early warning sign of global pollinator declines effects (Garibaldi et al. 2009).

Recommendation

Environmental education and civic awareness play a significant role in making a healthy environment as it helps individuals to recognize the difference between the essential requirements and limited natural resources. Changes in agricultural practices that restore habitats for beneficial arthropods (pollinators and natural enemies) by properly managing weeds within and around cropping systems.

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