A Sustainable Improvement in Food and Nutrition Security through Agricultural Biodiversity

T.Geetha Jebarathnam
PROFESSOR, SCHOOL OF AGRICULTURE,
BHARATH UNIVERSITY, CHENNAI.
geetha.agri@bharathuniv.ac.in

ABSTRACT

Historically, scientific breeding programs have primarily valued agricultural biodiversity as a source of traits that can be used to increase the productivity of livestock breeds and crop varieties. We contend that its potential to contribute to higher productivity is far greater. Agricultural biodiversity in particular needs to be used more widely in order to deliver a more secure food supply in a sustainable manner. A farming system's productivity can be raised by diversity in kingdoms, species, and genepools under a variety of growing conditions. Additionally, more diverse farming systems are typically more resilient to shocks, which improves food security. Diversity can lessen the effects of pests and diseases while maintaining and boosting soil fertility. Based on a variety of farming systems, a varied diet promotes better health and nutrition while also improving human productivity and standard of living. Not just as a source of traits but also as the foundation of more resilient farm ecosystems, agricultural biodiversity will be crucial to coping with the anticipated effects of climate change. A cross-sectoral approach is necessary to reevaluate the role of agricultural biodiversity in sustainable and secure food production because many of its benefits are cross-cutting political boundaries and manifest at various ecological and human scales.

[Keywords: agricultural biodiversity; food security; sustainability; nutrition; hunger

Introduction

Biological diversity that is pertinent to food and agriculture, as well as the biological diversity that makes up the agro-ecosystem, are both included in agricultural biodiversity. It manifests itself on multiple levels, ranging from the various ecosystems in which people cultivate crops and livestock to the various species breeds and varieties and the genetic diversity within each variety or breed. While a large portion of biodiversity is directly managed to provide the goods and services that humans require, a large portion is also important as a source of materials and for its contributions to ecosystem services like pollination, soil dynamics, and greenhouse gas emission control. Biological diversity components that are important to food and agriculture, as well as those that make up the agro-ecosystem, are included in the category of agricultural biodiversity. It is present on multiple levels, ranging from the various ecosystems in which people rear cattle and crops to the genetic diversity found in each species' various varieties and breeds. A large portion of biodiversity is not directly intended for production, but it is still significant as a source of materials and for its contributions to ecosystem services like pollination, soil dynamics, and greenhouse gas emission control. A smaller portion of biodiversity is directly managed to provide the goods and services that people need. Though recent worries about food availability suggest that it is appropriate to highlight evidence of agricultural biodiversity's importance to agricultural productivity and production, the value of preserving and utilizing agricultural biodiversity is not new [Jackson etal;2007]. Some have argued that the 2007–2008 "food price crisis" was a precursor to a new regime marked by more volatile and higher prices in many ways [Vidal;2010]. Drought in the Russian Federation and floods in Pakistan in 2010 had a significant impact on food prices and availability, underscoring the need to increase global food security. This case has two drawbacks that need to be addressed. To begin with, there is comparatively little evidence of the benefits derived from diversity itself because agricultural biodiversity was previously primarily valued for its traits. More recently, Jackson et al[2007] have maintained that local-scale experiments, which are typical of most agricultural research, are not always able to detect certain benefits, such as the insurance value of biodiversity and the heterogeneous composition of agro-ecosystems. Furthermore, it can be challenging to identify the specific advantages of utilizing agricultural biodiversity and to substantiate the causal links between various aspects of human livelihoods that it impacts. High lighting how important it is to increase food security worldwide. . Due to space constraints, we have chosen to concentrate on a few key production and consumption aspects here, especially those that affect sustainability. We have not gone into great detail about the numerous social, cultural, and conservation benefits that are also associated with agricultural biodiversity .

Plant biodiversity and ecosystem functioning

The application of ecological intensification through biodiversity management in agriculture is obviously still hampered by a number of issues.The ecological intensification of forestry is likewise impeded by comparable challenges. We anticipate that the latter will also be addressed by increased understanding of the advantages of biodiversity. Once established, the benefits of initial transitions should be self-sustaining, however legislative assistance may be necessary.The provisioning of ecosystem services and functions, such as biomass production, nutrient cycling support processes, soil carbon storage, pollination, and the decrease of pests and pathogens, is encouraged and stabilized by biodiversity [Conner etal;2007]. Agricultural systems have lost much of their biodiversity and are vulnerable to pests, diseases, and environmental stressors like drought. In intensive agriculture, the use of synthetic pesticides and fertilizers has detrimental effects on crop productivity as well as the environment, provided evidence from several field studies to show how nitrogen pollution (from agricultural runoff and aerial deposition) in terrestrial ecosystems leads to eutrophication and acidification, which in turn causes species loss and has cascading effects on community composition all the way up the food chain [Welch etal,2004].

Productivity and Stability

This is not a novel concept: ecosystems with greater genetic variety within species or greater species diversity overall frequently have higher productivity than simpler systems . The (non-agricultural) prairie ecosystems where Tilman[2006] and his colleagues have most thoroughly documented this are those where plots containing 16 species, for instance, produced 2.7 times more biomass than monocultures ,created species-rich and species-poor hay meadows in agricultural systems; after eight years, the richer meadows yielded 43% more hay than the species-poor fields, not just because the more diverse fields had more legumes for fertilization. More recent studies have shown that temporal stability is simultaneously promoted at multiple levels of ecosystem organization in grasslands through experimental manipulation of diversity . In Poland, the mean yield of barley varieties as pure stands was frequently outperformed by mixtures of the varieties . Higher productivity is also linked to more stable output; high-diversity plots were 70% more stable than monocultures, according to Tilman et al[2006].

Ecologists have long discussed the relationship between several metrics of ecosystem and food web stability and complexity. One version of stability is represented by Tilman's [2006] measure, which is the ratio of mean plot total biomass to standard deviation across time . Balancing the maintenance of diversity within a production system with appropriate (or available) management practices often involves significant trade-offs, and the right balance will vary depending on the production system and goal .In addition to being very productive per unit area, home gardens are among the world's most diversified production systems . For millions of small-scale farmers worldwide, they directly enhance output, revenue, and nutrition despite their often tiny size and high work intensity. Comparable outcomes have been observed in food production systems, especially in China. A report quoted by Zhang and Li [2003]states that "multiple cropping produces half of the total grain yield and accounts for one-third of all cultivated land area" . Today's numbers are undoubtedly higher. The group lead by Zhang and Li has conducted an extensive analysis of the consequences of agricultural biodiversity and has looked at some of the underlying mechanisms. When wheat is interplanted with maize, yield increases by 74%, whereas output increases by 53% when soybeans are used. Similar to how disease-resistant individuals in a field of mixed varieties of the same species exhibit greater tillering , Zhang and Li[2003] . Within a crop species, diversity also increases productivity. As demonstrated by Ceccarelli [1996]for barley, genetic diversity can lower crop failure risk in high stress circumstances, even when some varieties' yield levels under non-stress conditions may be lower. Numerous studies have indicated that traditional crop varieties and high levels of genetic and crop diversity worldwide are maintained by small-scale farmers due to a variety of factors, including risk avoidance, various usage needs, and stability .

In order to prevent vulnerability and extensive crop loss due to the impact of a specific biotic or abiotic stress on a crop, it is widely acknowledged at larger scales that crop variety diversity must be maintained in production systems.

Pests and Diseases

The utilization of various niches and the various roles that various plant groups play contribute to part of the yield gain linked to increased diversity. However, the primary reason for greater output and yield stability even in simpler agricultural systems is enhanced resilience to pest and disease outbreaks through effective exploitation of both intra- and inter-specific variation. Finckh[2000] and colleagues delineate multiple processes that underlie this phenomenon, ranging from the mere distance between vulnerable host plants and physical impediments to transmission to pathogen race rivalry that mitigates disease severity. In temperate and tropical trials, experimental combinations of potato cultivars susceptible to and resistant to late blight (*Phytophthora infestans*) exhibit less severe disease than monocultures.

The more valuable traditional varieties of rice are produced in greater quantities when resistant contemporary varieties act as a physical barrier to stop the spread of rice blast (*Magnaporthe grisea*) spores. Resistant modern varieties also provide physical support for susceptible traditional varieties that are more likely to lodge. Genetic diversity within a single species' fields will slow the evolution of pathogens and provide longer-term protection against the breakdown of resistance; however, varying the mixture's composition annually may encourage even greater diversity in the pathogen population, further delaying adaptation by lowering the selection pressure on distinct pathogen races. Owing to the nature of the protection, suitable mixes have the ability to simultaneously control multiple diseases, which increases their use. Global crop yields are reduced by around 40% annually due to pests . Oerke [2005]observes that “crop losses have not significantly decreased during the last 40 years, despite a clear increase in pesticide use”. As opposed to its use against diseases, the use of biodiversity to reduce damage caused by pests and macro-parasites is better documented, provided a number of examples, ranging in scale from the very local—harvesting lucerne fields in alternating strips preserves structural diversity and habitat for natural enemies of *Helicoverpa* spp.—to the landscape—parasitism rates on armyworm *Pseudaletia unipuncta* are higher in more complex land scapes .

A more thorough investigation of the mechanisms behind the impacts of altered biodiversity on diseases and pests has started. Positive and negative effects may be expected for various disorders, as noted by Keesing et al.[2010] . However, every example they give from agriculture suggests that increased biodiversity guards against illness. When it comes to rice blast, the distinct plant architecture of the types causes the canopy to be drier, which further inhibits the fungus growth. This is in addition to the larger spacing between vulnerable plants in a plot of mixed kinds, which effectively results in a drop in host abundance, that hosts exposed to pathogen strains more suited to different kinds can develop induced

Regulating and Supporting Ecosystem Services

A review of agricultural biodiversity's significance for these ecological services was conducted by Swift et al. and, more recently, by Hajjar et al.[2008] with regard to crop diversity. The degree of diversity required for various functions within agro-ecosystems is still up for debate. Saturation is attained at very low levels of species diversity, according to some research, although reducing diversity frequently has a negative impact on certain functions, according to other studies A variety of regulating and supporting ecosystem services, such as nutrient cycling, controlling water flow and storage, managing soil movement and properties, and controlling biological populations (including the previously mentioned control of pests and diseases), are essential to agricultural productivity. In simplified agricultural systems, inputs provided by humans have largely taken the place of these functions. Actually, an ecosystem can serve more than one purpose, and depending on the species or genetic makeup of the ecosystem, each function may work well. Swift et al[2008] emphasize the significance of preserving the overall diversity of the system in this regard, as well as the application of management techniques like mulching and conservation agriculture, which are likely to guarantee greater degrees of diversity in the production system. For instance, Milcu et al.[2008] adjusted earthworm density versus plant diversity gradient to determine why more species-rich grasslands produced higher yields. Plant assemblages with a higher proportion of legumes had higher rates of decomposition of plant litter; however, the effect was greater at higher plant diversity, suggesting that neither earthworm density nor plant diversity alone could Landscape heterogeneity is a crucial component of many production systems, involving a varied assembly of crop, animal, and agroforestry elements at various scales [Jackson etal; 2007]. Much of the diversity seen in agricultural landscapes, as previously mentioned, resides at scales larger than farms, and most agricultural experimentation fails to adequately capture this diversity's function and contribution.

The loss of species has recently drawn a lot of attention because pollination is a traditional and crucial ecosystem service . Pollination networks were reported by Memmot et al.[2004] to be comparatively resilient to the loss of pollinator species variety in simulation experiments , however some species—like bumble bees and some solitary bees—were particularly significant. But according to a recent assessment by Hajjar et al[2008] crop diversity within and across species increases pollinator availability and boosts productivity. observed that seed production for two brassica crops declined with increasing distance from the adjacent grassland and that growing isolation of habitat islands amid agricultural fields led in decreasing quantity and species diversity of flower-visiting bees. The relationship between pollinator and crop diversity serves as an excellent illustration of the significance of interactions between various elements of agricultural biodiversity. Increased diversity benefits pollinators and their abundance and activity, which in turn boosts the productivity of some of the various crops that are present in a production system. A colony of bees that are genetically diverse is also more likely to survive . Resilience, or the ability of an ecosystem to adapt to and recover from disturbance, is a function of all the mechanisms mentioned above and has been linked to the degree of connectedness within an ecosystem . The consequence of simplifying ecosystems is that those systems subsequently become more vulnerable to perturbations. This resilience to perturbation may be demonstrated by a smaller decline in productivity, a more quick rebound, and lower variability across time. All of these traits are supported by biodiversity.

Nutrition and Health

The biggest obstacle to food security at the moment is not increasing yields, particularly for the key nutrients like proteins and calories. A third of the world's population suffers from one or more of the micronutrient deficiencies sometimes grouped together as hidden hunger, and approximately one billion people still go hungry worldwide, despite the fact that significant progress is being made in alleviating protein-calorie deficits . Although Welch and Graham describe 49 “essential nutrients for sustaining human life”, iron, vitamin A, and iodine are likely the most significant micronutrients. Enough resources are needed for everyone's nutrition security. The burden of hunger and malnutrition is likely too great to accurately estimate, and the numbers in the short term fluctuate irrationally. According to a combined report on the State of Food Insecurity in the World 2010 by the World Food Programme and the Food and Agriculture Organization of the United Nations, 925 million people experienced chronic hunger in 2010. Furthermore, even in developing nations , the number of overweight and obese individuals currently exceeds that of those who are chronically hungry . The World Health Organization is currently analysing the results of a large survey that will provide more detailed insights. Previous approaches to treating micronutrient deficiencies have mostly relied on a medical model. These approaches have included fortification (such as adding iodine to salt), supplements (such as high doses of vitamin A), and so-called bio fortification, which involves boosting the micronutrient content of staple crops. Agricultural biodiversity may be a useful addition, even though each of these strategies has advantages . This strategy goes beyond using particular food ingredients to address particular deficiencies ; instead, it aims to increase the diversity of the diet in the strong conviction that doing so improves nutrition, including micronutrients as well as other crucial elements like fiber, and subsequently promotes better health.

There is some proof that eating a varied diet can reduce disease, morbidity, and death rates (compared to eating a certain diet component; see references in . The most noteworthy findings come from 11 developing nations and show that there is still a significant correlation between child development as measured by height-for-age Z scores and dietary diversity even after accounting for confounding variables like household wealth . Consequently, dietary variety lowers stunting. Furthermore, decreasing childhood malnutrition increases childhood survival in developing nations and positively affects adult economic productivity afterwards. Good evidence also suggests that a noticeable improvement in nutritional status occurs when even small amounts of foods derived from animals are added to the diet . Research conducted in India, for instance, has demonstrated a number of positive effects on yields, incomes, profits, the nutritional content of popular breakfast and snack foods, and female empowerment when it comes to the use of so-called minor millets among extremely poor farmers.

These findings also support the likelihood of these crops and their biological diversity being preserved in farmers' fields [Yenagi etal;2010]. It is anticipated that the numerous synergistic effects will improve food and nutrition security and ultimately improve health and well-being, even though it has not yet been feasible to show a direct impact on the nutritional status of participating villagers.

Climate Change

The fact that completely new weather patterns brought about by climate change will impact agriculture on all scales is becoming more and more evident . Numerous insect species' distribution and abundance have already shown significant changes , which is likely to have an impact on the spread of diseases and pests as well as the mechanisms in place to prevent them. To help farmers deal with climate change and increased climate variability, adaptability and resilience in production systems will be more crucial than ever. In fact, there is evidence that these factors are crucial already. Giving farmers and others access to a wider gene pool so they can choose their own adapted and adaptive populations could be a beneficial complementary approach, even in this field. Segregating populations from wide crosses, multi lines, mixtures, or even accessions from the boundaries of the typical growing range could be the form of these gene pools. This method appears to be more effective than breeding that depends on extra external inputs in hastening the adaptation of farming systems to altered conditions [Finck etal;2003].

Conclusion

Diversity at the species, ecosystem, and genetic levels directly improves many aspects of agricultural production. We still don't fully understand the nature and scope of these advantages, so more research is required to examine both the inherent advantages and the effects that appear at various scales. It is clear from the thorough experimental studies we have included in several of the preceding sections that implementing agricultural biodiversity more successfully entails more than just going back to the old ways. While some concepts and methods will be globally applicable, others may be limited by location and culture, it takes a scientific approach to comprehend how various forms of agricultural biodiversity contribute to the objectives of enhanced food and nutrition security and sustainability Beyond the production perspective covered in this paper, there will be a multitude of effects from increasing the deployment of biodiversity in agricultural systems. Initiatives to increase social resilience or food security through biodiversity may have unintended consequences on things like incomes, health, and cultural preservation. A single project's numerous case studies show how many other aspects of a family's life, including income, housing, education, and food security, can be enhanced by relatively straightforward interventions like including chicken farming into daily activities. Nonetheless, in order to take advantage of these opportunities, we must have a far larger body of knowledge.

Though the temptation to seek short-term solutions will always be present, these are unlikely to be long-term solutions or address the current issues surrounding an environmentally responsible agriculture that meets the needs of small-scale farmers worldwide. A greater release of greenhouse gases, depleted water supplies from mining, and degraded soils are the seeds of agricultural intensification strategies that have been employed nearly exclusively up to this point. Examples of these strategies include the replacement and supplementation of ecosystem function by human labor and petrochemical products. Intensification must be delivered through production systems that are not simplified. Diverse aspects will be involved, such as species inter cropping , varietal mixtures , and more comprehensive diversification plans [Batugal etal;2005]. Agricultural production and agriculture are undoubtedly back on the international agenda as a result of recent worries about high food prices and limited food availability. More people are realizing how difficult it is to increase production in a sustainable way while meeting the demands of a growing population in the face of changing climates. In light of this, it is evident that agricultural biodiversity is playing a more significant role than it did in the traditional paradigm—namely, as a source of traits for the constant, iterative improvement of staple crops—and is crucial to better production systems. Certainly, there are other aspects of food systems and production, like harvesting and post-harvest storage, small-scale processing and domestic. This strategy is especially useful in marginal areas and other places where diverse production systems are still prevalent, but there is also a need to focus more in the future on better utilizing agricultural biodiversity in areas that have lost it. To increase output, strengthen ecosystem functions, and allow for adaptability, diversity will be necessary.

References :

1.Batugal, P.; Oliver, J. *Poverty Reduction in Coconut Growing Communities 3: Project Achievements and Impact*; IPGRI-APO: Serdang, Malaysia, 2005. [**Google Scholar**]

2.Ceccarelli, S. Adaptation to low/high input cultivation. *Euphytica* **1996**, *92*, 203–214. [**Google Scholar**]

3.Conner, A.J.; Mercer, C.F. Breeding for success: Diversity in action. *Euphytica* **2007**, *154*, 261–262. [**Google Scholar**]

4.Finckh, M.R.; Gacek, E.S.; Goyeau, H.; Lannou, C.; Merz, U.; Mundt, C.C.; Munk, L.; Nadziak, J.; Newton, A.C.; De Vallavielle-Pope, C.; Wolfe, M.S. Cereal variety and species mixtures in practice, with emphasis on disease resistance. *Agronomie* **2000**, *20*, 813–837. [**Google Scholar**]

5.Global Footprint Network (2022). Available at: http://www.footprintnetwork.org.
Google Scholar

6.Hajjar, R.; Jarvis, D.I.; Gemmill-Herren, B. The utility of crop genetic diversity in maintaining ecosystem services. *Agr. Ecosyst. Environ.* **2008**, *123*, 261–270. [Google Scholar]

7.Jackson, L.E.; Pascual, U.; Hodgkin, T. Utilizing and conserving agrobiodiversity in agricultural landscapes. *Agr. Ecosyst. Environ.* **2007**, *121*, 196–210. [Google Scholar]

8.Keesing, F.; Belden, L.K.; Daszak, P.; Dobson, A.; Harvell, C.D.; Holt, R.D.; Hudson, P.; Jolles, A.; Jones, K.E.; Mitchell, C.E.; Myers, S.S.; *et al*. Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature* **2010**, *468*, 647–652. [Google Scholar]

9.Memmott, J.; Waser, N.M.; Price, M.V. Tolerance of pollination networks to species extinctions. *Biol. Sci. B* **2004**, *271*, 2605–2611. [Google Scholar]

10.Milcu, A.; Partsch, S.; Scherber, C.; Weisser, W.W.; Scheu, S. Earthworms and legumes control litter decomposition in a plant diversity gradient. *Ecology* **2008**, *89*, 1872–1882. [Google Scholar]

11.Oerke, E.C. Crop losses to pests. *J. Agr. Sci.* **2005**, *144*, 31–43. [Google Scholar]

12.Swift, M.J.; Izac, A.M.N.; Van Noordwijk, M. Biodiversity and ecosystem services in agricultural landscapes: Are we asking the right questions? *Agr. Ecosyst. Environ.* **2004**, *104*, 113–134. [Google Scholar]

13.Tilman, D.; Reich, P.B.; Knops, J.M.H. Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature* **2006**, *441*, 629–632. [Google Scholar]

14.Vidal, J. *Global Food Crisis Forecast as Prices Reach Record Highs*; The Guardian: London, UK, 2010; p. 25. [Google Scholar]

15.Welch, R.M.; Graham, R.D. Breeding for micronutrients in staple food crops from a human nutrition perspective. *J. Exp. Bot.* **2004**, *55*, 353–364. [Google Scholar]

16.Yenagi, N.B.; Handigol, J.A.; Bala Ravi, S.; Mal, B.; Padulosi, S. Nutritional and technological advancements in the promotion of ethnic and novel foods using the genetic diversity of minor millets in India. *Indian J. Plant Genet. Resour.* **2010**, *23*, 82–86. [Google Scholar]

17 Zhang, F.; Li, L. Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency. *Plant Soil* **2003**, *248*, 305–312. [Google Scholar]