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"Agriculture and the Environment: Knowledge and Technology to Feed the World"

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https://www.ucsusa.org/sites/default/files/attach/2015/11/ucs-counting-on-agroecology-2015.pdf

Union of Concerned Scientists – Fact Sheet

Counting On Agroecology

Why We Should Invest More in the Transition to Sustainable Agriculture

Across the United States, farms and ranches produce vast quantities of food, fiber, and fuel that are available at relatively affordable prices. This abundance is a measure of success, yet it often comes at the expense of the environment, public health, and even long-term agricultural productivity (Liebman and Schulte 2015; Steffen at al. 2015; Kremen and Miles 2012). Many fields are planted with the same crop year after year, subjected to frequent and intensive mechanical soil disruption to suppress weeds and incorporate crop residues, and left bare when not in production. Such practices can erode, pollute, and in other ways degrade the soil. Similarly, large amounts of fertilizer are often applied to maximize productivity, but much of it either is lost via surface runoff or groundwater leaching, leading to toxic algal blooms and aquatic dead zones, or escapes to the atmosphere, where it contributes to climate change.

The combination of heavy herbicide use with the widespread planting of herbicide-resistant crops is another problem. This has led to the evolution of herbicide-resistant "superweeds," the drifting of herbicides onto neighboring farms, and new challenges for certified organic systems and other farms producing crops that are not resistant to herbicides. Intensive pesticide use has also raised concerns about the environmental impacts and human health risks of exposure to these chemicals (Shelton et al. 2014; Hayes et al. 2011).

Taken together, these issues point to the urgent need to enhance the sustainability of agriculture. The good news is that studies have shown that agroecological systems, which feature farming practices that work with nature, can provide long-term environmental benefits while maintaining productivity (Davis et al. 2012). But maximizing the potential of such systems requires investment, particularly in research and technical assistance for farmers. Current levels of investment are not meeting this need.

A Classification System for Sustainable Farm Practices

As evidence of the impacts of industrial farming on the environment and society mounts, there is growing attention to the need to redesign the food system. As part of this effort, one internationally recognized leader in the field of agroecology established a framework for classifying agricultural practices based on their potential to make the system more sustainable (Gliessman 2014). Practices are grouped in five "levels," ranging from incremental to transformative.

Level 1 practices focus on increasing efficiency to improve the sustainability of farms and food production. Due to such efforts, many farmers today need fewer off-farm inputs—fertilizers, pesticides, water, and energy—to maintain productivity. Waste reduction at the farm and during processing also prevents the unnecessary overuse of limited resources. Improved crop and animal-product yields are also hypothesized to improve production efficiency. Such advances can serve as important steppingstones to a more sustainable food system, although farmers who adopt them typically still rely on high-risk or limited resources.

Level 2 efforts substitute less-damaging inputs and practices for those that currently pose the highest risks. For example, many farmers replace chemical fertilizers with compost and cover crops, adopt nonchemical pest-control strategies, or till fields less frequently. Organic farming systems commonly use substitutes for the most harmful inputs. As at Level 1, such measures reduce agriculture's environmental impact but leave intact the underlying input-dependent and biologically simplified model of farming.

Level 3 efforts integrate agroecological practices to enhance complementary interactions in food and farming systems to meet food needs while providing additional environmental and public health benefits (Ponisio et al. 2015; Gliessman 2014; Kremen and Miles 2012). This science of managing lands to boost the health of farms, ranches, and surrounding environments embraces systemic approaches to designing and managing sustainable food systems, from farm production to food distribution. Farms managed with Level 3 practices, such as complex crop rotations and crop and animal diversification, can improve the health of the soil, reduce pests, support pollinators, and mitigate climate change, while avoiding the negative environmental footprint common to industrial farming systems (Gliessman 2014; Kremen and Miles 2012; Reganold et al. 2011).

Level 4 systems reinforce connections between producers and consumers to address the interdependence of agriculture and society (De Schutter 2014; Gliessman 2014). These relationships can be supported through policies and incentives that engage communities and businesses in sustainable operations. Robust sustainability can be achieved when the agroecological practices of Level 3 are combined with Level 4 socioeconomic supports to result in products that consumers value, demand, and can access.

Level 5 systems fully develop and integrate the agroecological practices of Level 3 and the alternative market relationships of Level 4 to support a global sustainable food system grounded in social change. This level represents the final stage of conversion in the classification system.

https://www.nature.com/scitable/knowledge/library/sustainable-agriculture-23562787

Sustainable Agriculture

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History and Key Concepts

Agriculture has changed dramatically since the end of World War II. Food and fiber productivity has soared due to new technologies, mechanization, increased chemical use, specialization, and government policies that favored maximizing production and reducing food prices. These changes have allowed fewer farmers to produce more food and fiber at lower prices.

Although these developments have had many positive effects and reduced many risks in farming, they also have significant costs. Prominent among these are topsoil depletion, groundwater contamination, air pollution, greenhouse gas emissions, the decline of family farms, neglect of the living and working conditions of farm laborers, new threats to human health and safety due to the spread of new pathogens, economic concentration in food and agricultural industries, and disintegration of rural communities.

A growing movement has emerged during the past four decades to question the necessity of these high costs and to offer innovative alternatives. Today this movement for sustainable agriculture is garnering increasing support and acceptance within our food production systems. Sustainable agriculture integrates three main goals – environmental health, economic profitability, and social equity (Figure 1). A variety of philosophies, policies and practices have contributed to these goals, but a few common themes and principles weave through most definitions of sustainable agriculture.

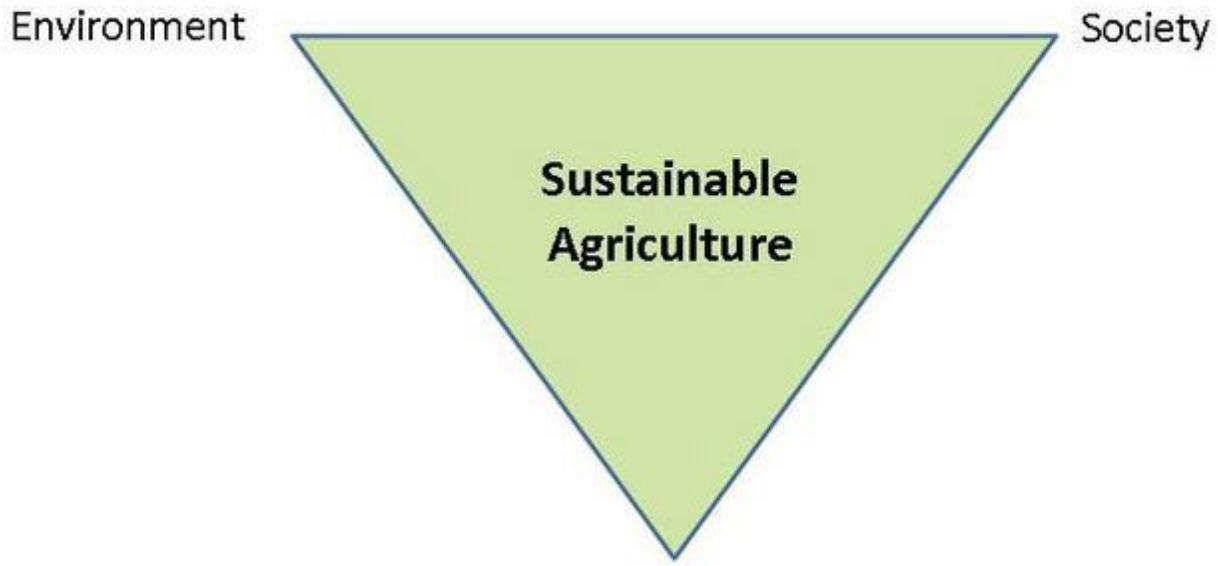

Figure 1
Sustainable agriculture gives equal weight to environmental, social, and economic concerns in agriculture.

Agricultural sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, long-term stewardship of both natural and human resources is of equal importance to short-term economic gain. Stewardship of human resources includes consideration of social responsibilities such as working and living conditions of laborers, the needs of rural communities, and consumer health and safety both in the present and the future. Stewardship of land and natural resources involves maintaining or enhancing the quality of these resources and using them in ways that allow them to be regenerated for the future. Stewardship considerations must also address concerns about animal welfare in farm enterprises that include livestock.

An agroecosystems and food systems perspective is essential to understanding sustainability. Agroecosystems are envisioned in the broadest sense, from individual fields to farms to ecozones. Food systems, which include agroecosystems plus distribution and food consumption components, similarly span from farmer to local community to global population. An emphasis on a systems perspective allows for a comprehensive view of our agricultural production and distribution enterprises, and how they affect human communities and the natural environment. Conversely, a systems approach also gives us the tools to assess the impact of human society and its institutions on farming and its environmental sustainability.

Studies of different types of natural and human systems have taught us that systems that survive over time usually do so because they are highly resilient, adaptive, and have high diversity. Resilience is critical because most agroecosystems face conditions (including climate, pest populations, political contexts, and others) that are often highly unpredictable and rarely stable in the long run. Adaptability is a key component of resilience, as it may not always be possible or desirable for an agroecosystem to regain the precise form and function it had before a disturbance, but it may be able to adjust itself and take a new form in the face of changing conditions. Diversity often aids in conferring adaptability,

because the more variety that exists within a food system, whether in terms of types of crops or cultural knowledge, the more tools and avenues a system will have to adapt to change.

An agroecosystem and food system approach also implies multi-pronged efforts in research, education, and action. Not only researchers from various disciplines, but also farmers, laborers, retailers, consumers, policymakers and others who have a stake in our agricultural and food systems have crucial roles to play in moving toward greater agricultural sustainability.

Finally, sustainable agriculture is not a single, well-defined end goal. Scientific understanding about what constitutes sustainability in environmental, social, and economic terms is continuously evolving and is influenced by contemporary issues, perspectives, and values. For example, agriculture's ability to adapt to climate change was not considered a critical issue 20 years ago, but is now receiving increasing attention. In addition, the details of what constitutes a sustainable system may change from one set of conditions (e.g., soil types, climate, labor costs) to another, and from one cultural and ideological perspective to another, resulting in the very term "sustainable" being a contested term. Therefore, it is more useful and pertinent to think of agricultural systems as ranging along a continuum from unsustainable to very sustainable, rather than placed in a sustainable/unsustainable dichotomy.

Sustainable Agriculture and the Management of Natural Resources

When the production of food and fiber degrades the natural resource base, the ability of future generations to produce and flourish decreases. The decline of ancient civilizations in Mesopotamia, the Mediterranean region, Pre-Columbian southwest U.S. and Central America is believed to have been strongly influenced by natural resource degradation from non-sustainable farming and forestry practices. A sustainable agriculture approach seeks to utilize natural resources in such a way that they can regenerate their productive capacity, and also minimize harmful impacts on ecosystems beyond a field's edge. One way that farmers try to reach these goals is by considering how to capitalize on existing natural processes, or how to design their farming systems to incorporate crucial functions of natural ecosystems. By designing biologically-integrated agroecosystems that rely more on the internal cycling of nutrients and energy, it is often possible to maintain an economically viable production system with fewer potentially toxic interventions. For example, farmers aiming for a higher level of environmental sustainability might consider how they can reduce their use of toxic pesticides by bringing natural processes to bear on limiting pest populations. This might happen, for example, by planting hedgerows along field edges, or ground covers between rows, thereby providing habitat for insects and birds that prey on the pests, or by planting more diverse blends of crops that confuse or deflect pests (Figure 2). Maintaining a high degree of genetic diversity by conserving as many crop varieties and animal breeds as possible will also provide more genetic resources for breeding resistance to diseases and pests.

Figure 2
A clover and grass cover crop adds biodiversity to an almond orchard, which aids in nutrient cycling and provides habitat for beneficial insects, while also building soil organic matter.

Conservation of resources critical for agricultural productivity also means taking care of soil so that it maintains its integrity as a complex and highly structured entity composed of mineral particles, organic matter, air, water, and living organisms. Farmers interested in long-term sustainability often prioritize caring for the soil, because they recognize that a healthy soil promotes healthy crops and livestock. Maintaining soil functioning often means a focus on maintaining or even increasing soil organic matter. Soil organic matter functions as a crucial source and sink for nutrients, as a substrate for microbial activity, and as a buffer against fluctuations in acidity, water content, contaminants, etc. Furthermore, the buildup of soil organic matter can help mitigate the increase of atmospheric CO_2 and therefore climate change. Another important function of soil organic matter is inducing a better soil structure, which leads to improved water penetration, less runoff, better drainage, and increased stability, thereby reducing wind and water erosion.

Due to a high reliance on chemical fertilizers, agroecosystem functioning has been disconnected from the internal cycling of key plant nutrients such as nitrogen and phosphorus. Phosphate minerals for fertilizer are currently mined, but global reserves are predicted to sustain food production for only another 50 to 100 years. Consequently, phosphate prices are anticipated to rise unless new reserves are discovered and innovations in recovery of phosphates from waste are developed. The recycling of nitrogen and phosphorus (at the farm and regional scale), improving efficiencies of fertilizer applications, and relying on organic nutrient sources (animal and green manures) are important elements of sustainable agriculture (Figure 3). Recycling of nutrients is facilitated by a diversified

agriculture in which livestock and crop production are more spatially integrated. For these reasons, extensive mixed crop-livestock systems, particularly in developing countries, could significantly contribute to future agricultural sustainability and global food security.

Figure 3
The Quesungual agroforestry system in Honduras: Maize, beans, and squash are cultivated between selectively preserved trees that provide green manure and/or fruit and/or firewood. The practice has been shown to reduce soil erosion, increase yield, increase biotic activity, improve soil structure, and enhance soil organic matter accumulation.

In many parts of the world, water for agriculture is in short supply and/or its quality is deteriorating. Overdraft of surface waters results in disturbance of key riparian zones, while overdraft of groundwater supplies threatens future irrigation capacity. Salinization, nutrient overloads, and pesticide contamination are widespread water quality issues. Selection and breeding of more drought- and salt-tolerant crop species and hardier animal breeds, use of reduced-volume irrigation systems, and management of soils and crops to reduce water loss are all ways to use water more efficiently within sustainable agroecosystems.

Modern agriculture is heavily dependent on non-renewable energy sources, especially petroleum. The continued use of these non-renewable sources cannot be sustained indefinitely, yet to abruptly abandon our reliance on them would be economically catastrophic. In sustainable agriculture, the goal is to reduce the input of external energy and to substitute non-renewable energy sources with renewable sources (e.g., solar and wind power, biofuels from agricultural waste, or, where economically feasible, animal or human labor).

Sustainable Agriculture and Society

Agroecosystems cannot be sustainable in the long run without the knowledge, technical competence, and skilled labor needed to manage them effectively. Given the constantly changing and locality-specific nature of agriculture, sustainability requires a diverse and adaptive knowledge base, utilizing both formal, experimental science and farmers' own on-the-ground local knowledge. Social institutions that promote education of both farmers and scientists, encourage innovation, and promote farmer-researcher partnerships can increase agricultural productivity as well as long-term sustainability (Figure 4).

Figure 4
A farmer field school in the Democratic Republic of Congo encourages farmers to learn about sustainable farming practices from visiting teachers as well as from each other's on-the-ground experiences.

Questions of social equity often arise in discussions of sustainable agriculture. Wages for farm labor are so low in most industrialized countries that their agricultural sectors rely substantially on migratory labor from poorer nations, leaving farmers vulnerable to changing immigration policies and placing burdens on government social services. The questionable legal status of many of these workers also contributes to their generally low pay and standard of living, lack of job security, lack of opportunities for upward mobility, and exemptions from occupational safety protections considered standard in other industries. Pooling resources among many farmers to provide better housing, sharing labor among farms with different crops to even out the seasonality of work opportunities, shared equity in farm profits, mentoring workers to acquire and operate their own farms, and working on innovative ways to

provide affordable health insurance and educational opportunities for employees are all alternative ways to increase labor equity and social justice.

Increasing consolidation of food manufacturers and marketers and of farm input suppliers means that farmers lack the economic power to negotiate better prices for their inputs and crops. This means their profit margins get squeezed, leaving many farmers with few resources to improve environmental and working conditions. Banding together in production, processing, or marketing cooperatives is one way that farmers can increase their relative economic power. Performing some processing functions on-farm before selling their crops, producing higher-value specialty crops, building direct marketing opportunities that bypass middlemen, and looking for niche markets are other ways that farmers can capture a larger share of the economic value of what they produce. Policies regulating consolidation can also protect farmers in the long-term.

Due to these economic pressures on farmers, many rural communities have become poorer as farms and associated local agricultural enterprises go out of business. Economic development policies and tax structures that encourage more diversified agricultural production on family farms can form a foundation for healthier rural economies. Within the limitations of the market structure, consumers can also play a role; through their purchases, they send strong messages to producers, retailers and others in the system about what they think is important, including environmental quality and social equity.

Finally, some of the same economic pressures that have hurt on-farm sustainability have also created social equity concerns for consumers in low-income communities, who are often left with little access to healthy food as conventional supermarkets move to more lucrative neighborhoods to bolster slim profit margins. Food production and marketing arrangements to bolster community food security, including community and home gardens, farmers markets, the use of fresh local farm produce in school meal programs, and local food cooperatives represent efforts to address these concerns (Figure 5). Moreover, a food systems approach also takes into account the impacts of farming practices on the safety and nutritional qualities of the final food products that reach consumers, for example by minimizing or eliminating toxic residues.

Figure 5
Instruction in school gardens and other public gardens helps children and their families learn to grow fruits and vegetables around their own homes or in community garden plots.

Conclusion

Social, economic, and environmental sustainability are closely intertwined and necessary components for a truly sustainable agriculture. For example, farmers faced with poverty are often forced to mine natural resources like soil fertility to make ends meet, even though environmental degradation may hurt their livelihoods in the long run. Only by creating policies that integrate social, environmental, and economic interests can societies promote more sustainable agricultural systems.

Acknowledgements

Feenstra, G., Ingels, C., Campbell, D. What is Sustainable Agriculture? University of California Sustainable Agriculture Research and Education Program. http://asi.ucdavis.edu/sarep/about/def

Glossary

Agroecosystem* - an agricultural system understood as a set of complementary relationships between living organisms (including crops and/or livestock) and non-living components of their environment within a certain physical area.

Ecozone - a broad geographic area encompassing a distinctive pattern of climate conditions, type of landscape, and species of plants and animals.

Food System* - the interconnected "meta-system" (collection of systems) composed of agroecosystems, their economic, social, cultural, and technological support systems, and systems of food distribution and consumption.

Green Manure* - Organic matter added to the soil when a crop (usually specifically grown for this purpose) is tilled in.

Resilience - Ability to rebound or recover from adversity. In the context of an agroecosystem or food system, it is the ability of that system to remain viable when affected by adverse forces, such as pest infestations, environmental degradation, economic downturns, etc.

Adaptability - Ability to change form and/or function in response to changing conditions. In the context of an agroecosystem and food system, it is the ability to change some components of itself and/or how it is structured based on changing conditions, while still maintaining its viability in providing products and services useful to humans over the long run.

*definitions adapted directly from Gliessman 2000.

https://www.nature.com/scitable/knowledge/library/soil-the-foundation-of-agriculture-84224268

Soil: The Foundation of Agriculture

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Throughout human history, our relationship with the soil has affected our ability to cultivate crops and influenced the success of civilizations. This relationship between humans, the earth, and food sources affirms soil as the foundation of agriculture.

Human society has developed through utilization of our planet's resources in amazingly unique, creative, and productive ways that have furthered human evolution and sustained global societies. Of these resources, soil and water have provided humans with the ability to produce food, through agriculture, for our sustenance. In exploring the link between soil and agriculture, this article will highlight 1) our transition from hunter-gatherer to agrarian societies; 2) the major soil properties that contribute to fertile soils; 3) the impacts of intensive agriculture on soil degradation; and 4) the basic concepts of sustainable agriculture and soil management. These topics will be discussed to demonstrate the vital role that soils play in our agriculturally-dependent society.

Agriculture and Human Society

Human use and management of soil and water resources have shaped the development, persistence, decline, and regeneration of human civilizations that are sustained by agriculture (Harlan 1992, Hillel 1992). Soil and water are essential natural resources for our domesticated animal- and plant-based food production systems. Although of fundamental importance today, agriculture is a relatively recent human innovation that spread rapidly across the globe only 10,000 to 12,000 years ago (Diamond 1999, Montgomery 2007, Price & Gebauer 1995, Smith 1995), during the Agricultural Revolution. This short, yet highly significant period of time, represents less than 0.3 % of the more than four million years of human evolution as bipedal hominids and ultimately Homo sapiens. In agriculturally-based societies during the last ten millennia, humans have developed complex, urban civilizations that have cycled through periods of increasing complexity, awe-inspiring intellectual achievement, persistence for millennia, and, in some instances, perplexing decline (Trigger 2003). In many cases, stressed, declining civilizations adapted, or reemerged, into new or similar complex cultures (Schwartz & Nichols 2006).

Through such fluctuations, we have remained dependent on a relatively small number of crop and animal species for food, and on integrated soil-water systems that are essential for their production. There is no doubt that our modern human society has developed to the point that we cannot exist without agriculture.

It is clear that agriculture sustains and defines our modern lives, but it is often disruptive of natural ecosystems. This is especially true for plant communities, animal populations, soil systems, and water resources. Understanding, evaluating, and balancing detrimental and beneficial agricultural disturbances of soil and water resources are essential tasks in human efforts to sustain and improve human well-being. Such knowledge influences our emerging ethics of sustainability and responsibility to human populations and ecosystems of the future.

Although agriculture is essential for human food and the stability of complex societies, almost all of our evolution has taken place in small, mobile, kin-based social groups, such as bands and tribes (Diamond 1999, Johanson & Edgar 2006). Before we became sedentary people dependent on agriculture, we were largely dependent on wild plant and animal foods, without managing soil and water resources for food production. Our social evolution has accelerated since the Agricultural Revolution and taken place synergistically with human biological evolution, as we have become dependent on domesticated plants and animals grown purposefully in highly managed, soil-water systems.

Figure 3: Dallas, South Dakota: tractor and farm equipment buried by soil transported by wind (May 13, 1936). Figure 3 is a stunning photograph demonstrating the devastating effects of this severe wind erosion. The Dust Bowl made soil erosion a high priority in the American public consciousness of the 1930s, and it remains a top priority today.

Photo courtesy of USDA.

Today, agricultural fields are not immune to the forces of nature (e.g., moving water, blowing wind, extremes of temperature) that caused soil erosion in the past. Figure 4 shows the severe effects of surface runoff and soil loss in the northwestern United States. Implementation of agricultural best management practices (BMPs), and through the practice of conservation agriculture, the rate of soil loss can be reduced to approximately equal the rate of soil formation, although often still greater than that in natural systems. In addition to soil erosion, intensive land use has resulted in deforestation, water shortages, and rapidly increasing desertification of vast areas of the globe, all of which threaten the sustainability of our agricultural systems.

Sustainable Soil Management

It is evident that, in order to maintain and increase food production, efforts to prevent soil degradation must become a top priority of our global society. Current population models predict a global population of between 8 and 10 billion in the next 50 years (Bongaarts 2009, Lutz et al. 2001) and a two-fold increase in food demand (Alexandratos 1999, Tilman et al. 2002). If mismanagement of soil resources continues to diminish the fertility of the soil and the amount of productive arable land (Pimentel et al. 1995), then we will have lost a precious and essential pillar of sustainable agriculture (Tilman 1999). Sustainable agriculture is an approach to farming that focuses on production of food in a manner that can be maintained with minimal degradation of ecosystems and natural resources. This sustainable approach to agriculture strives to protect environmental resources, including soil, and provide economic profitability while maintaining social equity (Brodt et al. 2011). The concept of sustainable agriculture is often misinterpreted to mean that chemical fertilizers and pesticides should never be used. This notion is incorrect, as sustainable agriculture should embrace those practices that provide the most beneficial services for agroecosystems and encourage long-term production of food supplies in a cultural context of the region. It cannot be overstressed that sustainable practices should not only consider crop production and profit, but must include land management strategies that reduce soil erosion and protect water resources. By embracing certain modern-day technologies, proven BMPs, and learning from the past, our society will be able to continue to conserve soil resources and produce food supplies sufficient to meet current and future population demands.

Figure 4: Damage to agricultural field in Washington (United States) resulting from water erosion.
Photo courtesy of USDA

https://www.epa.gov/safepestcontrol/integrated-pest-management-ipm-principles

Integrated Pest Management (IPM) Principles

What is IPM?

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

How do IPM programs work?

IPM is not a single pest control method but, rather, a series of pest management evaluations, decisions and controls. In practicing IPM, growers who are aware of the potential for pest infestation follow a four-tiered approach. The four steps include:

- **Set Action Thresholds**
  Before taking any pest control action, IPM first sets an action threshold, a point at which pest populations or environmental conditions indicate that pest control action must be taken. Sighting a single pest does not always mean control is needed. The level at which pests will either become an economic threat is critical to guide future pest control decisions.
- **Monitor and Identify Pests**
  Not all insects, weeds, and other living organisms require control. Many organisms are innocuous, and some are even beneficial. IPM programs work to monitor for pests and identify them accurately, so that appropriate control decisions can be made in conjunction with action thresholds. This monitoring and identification removes the possibility that pesticides will be used when they are not really needed or that the wrong kind of pesticide will be used.
- **Prevention**
  As a first line of pest control, IPM programs work to manage the crop, lawn, or indoor space to prevent pests from becoming a threat. In an agricultural crop, this may mean using cultural methods, such as rotating between different crops, selecting pest-resistant varieties, and planting pest-free rootstock. These control methods can be very effective and cost-efficient and present little to no risk to people or the environment.
- **Control**
  Once monitoring, identification, and action thresholds indicate that pest control is required, and preventive methods are no longer effective or available, IPM programs then evaluate the proper control method both for effectiveness and risk. Effective, less risky pest controls are chosen first, including highly targeted chemicals, such as pheromones to disrupt pest mating, or mechanical control, such as trapping or weeding. If further monitoring, identifications and action thresholds indicate that less *risky* controls are not working, then additional pest control methods would be employed, such as targeted spraying of pesticides. Broadcast spraying of non-specific pesticides is a last resort.

Do most growers use IPM?

With these steps, IPM is best described as a continuum. Many, if not most, agricultural growers identify their pests before spraying. A smaller subset of growers use less risky pesticides such as pheromones. All of these growers are on the IPM continuum. The goal is to move growers further along the continuum to using all appropriate IPM techniques.

How do you know if the food you buy is grown using IPM?

In most cases, food grown using IPM practices is not identified in the marketplace like *organic* food. There is no national certification for growers using IPM, as the United States Department of Agriculture has developed for organic foods. Since IPM is a complex pest control process, not merely a series of practices, it is impossible to use one IPM definition for all foods and all areas of the country. Many individual commodity growers, for such crop as potatoes and strawberries, are working to define what IPM means for their crop and region, and IPM-labeled foods are available in limited areas. With definitions, growers could begin to market more of their products as *IPM-Grown*, giving consumers another choice in their food purchases.

If I grow my own fruits and vegetables, can I practice IPM in my garden?

Yes, the same principles used by large farms can be applied to your own garden by following the four-tiered approach outlined above. For more specific information on practicing IPM in your garden, you can contact your state Extension Services for the services of a Master Gardener.

https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-agriculture-and-food-supply_.html

Climate Impacts on Agriculture and Food Supply

Overview

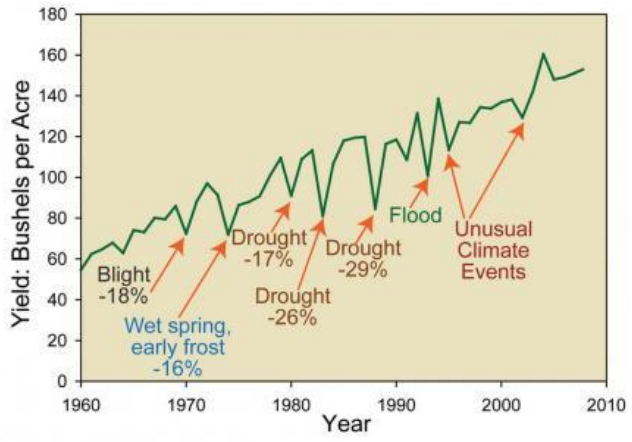
Key Points

- Moderate warming and more carbon dioxide in the atmosphere may help some plants to grow faster. However, more severe warming, floods, and drought may reduce yields.
- Livestock may be at risk, both directly from heat stress and indirectly from reduced quality of their food supply.
- Fisheries will be affected by changes in water temperature that make waters more hospitable to invasive species and shift the ranges or lifecycle timing of certain fish species.

Agriculture is an important sector of the U.S. economy. The crops, livestock, and seafood produced in the United States contribute more than $300 billion to the economy each year. When food-service and other agriculture-related industries are included, the agricultural and food sectors contribute more than $750 billion to the gross domestic product.

Agriculture and fisheries are highly dependent on the climate. Increases in temperature and carbon dioxide (CO2) can increase some crop yields in some places. But to realize these benefits, nutrient levels, soil moisture, water availability, and other conditions must also be met. Changes in the frequency and severity of droughts and floods could pose challenges for farmers and ranchers and threaten food safety. Meanwhile, warmer water temperatures are likely to cause the habitat ranges of many fish and shellfish species to shift, which could disrupt ecosystems. Overall, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past. The effects of climate change also need to be considered along with other evolving factors that affect agricultural production, such as changes in farming practices and technology.

Impacts on Crops



Despite technological improvements that increase corn yields, extreme weather events have caused significant yield reductions in some years. Source: USGCRP (2009)

Crops grown in the United States are critical for the food supply here and around the world. U.S. farms supply nearly 25% of all grains (such as wheat, corn, and rice) on the global market.[4] Changes in temperature, atmospheric carbon dioxide (CO_2), and the frequency and intensity of extreme weather could have significant impacts on crop yields.

For any particular crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction. In some areas, warming may benefit the types of crops that are typically planted there, or allow farmers to shift to crops that are currently grown in warmer areas. Conversely, if the higher temperature exceeds a crop's optimum temperature, yields will decline.

- Higher CO_2 levels can affect crop yields. Some laboratory experiments suggest that elevated CO_2 levels can increase plant growth. However, other factors, such as changing temperatures, ozone, and water and nutrient constraints, may counteract these potential increases in yield. For example, if temperature exceeds a crop's optimal level, if sufficient water and nutrients are not available, yield increases may be reduced or reversed. Elevated CO_2 has been associated with reduced protein and nitrogen content in alfalfa and soybean plants, resulting in a loss of quality. Reduced grain and forage quality can reduce the ability of pasture and rangeland to support grazing livestock.
- More extreme temperature and precipitation can prevent crops from growing. Extreme events, especially floods and droughts, can harm crops and reduce yields. For example, in 2010 and 2012, high nighttime temperatures affected corn yields across the U.S. Corn Belt, and premature budding due to a warm winter caused $220 million in losses of Michigan cherries in 2012.
- Dealing with drought could become a challenge in areas where rising summer temperatures cause soils to become drier. Although increased irrigation might be possible in some places, in other places water supplies may also be reduced, leaving less water available for irrigation when more is needed.
- Many weeds, pests, and fungi thrive under warmer temperatures, wetter climates, and increased CO_2 levels. Currently, U.S. farmers spend more than $11 billion per year to fight weeds, which compete with crops for light, water, and nutrients. The ranges and distribution of weeds and pests are likely to increase with climate change. This could cause new problems for farmers' crops previously unexposed to these species.
- Though rising CO_2 can stimulate plant growth, it also reduces the nutritional value of most food crops. Rising levels of atmospheric carbon dioxide reduce the concentrations of protein and essential minerals in most plant species, including wheat, soybeans, and rice. This direct effect of rising CO_2 on the nutritional value of crops represents a potential threat to human health. Human health is also threatened by increased pesticide use due to increased pest pressures and reductions in the efficacy of pesticides.

Impacts on Livestock

Americans consume more than 36 million metric tons of meat and poultry annually. Livestock and poultry account for over half of U.S. agricultural cash receipts, often over $100 billion per year. Changes in climate could affect animals both directly and indirectly.

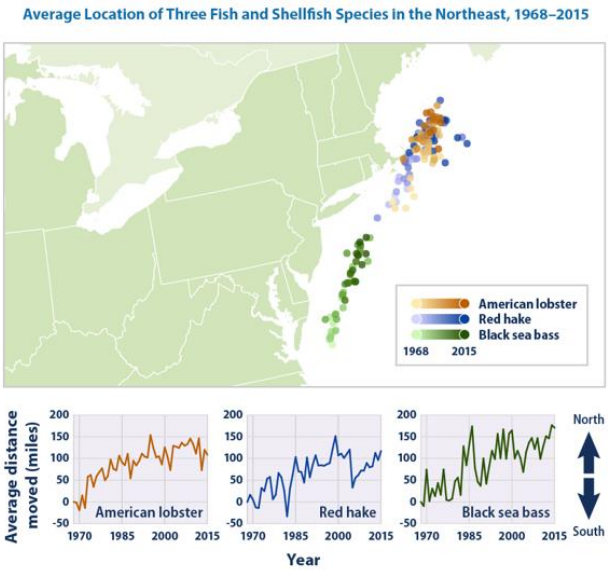
- Heat waves, which are projected to increase under climate change, could directly threaten livestock. In 2011, exposure to high temperature events caused over $1 billion in heat-related losses to agricultural producers. Heat stress affects animals both directly and indirectly. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce milk production.
- Drought may threaten pasture and feed supplies. Drought reduces the amount of quality forage available to grazing livestock. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation. For animals that rely on grain, changes in crop production due to drought could also become a problem.
- Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of spring and warmer winters could allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens could thrive.
- Potential changes in veterinary practices, including an increase in the use of parasiticides and other animal health treatments, are likely to be adopted to maintain livestock health in response to climate-induced changes in pests, parasites, and microbes. This could increase the risk of pesticides entering the food chain or lead to evolution of pesticide resistance, with subsequent implications for the safety, distribution, and consumption of livestock and aquaculture products.

- Increases in carbon dioxide (CO_2) may increase the productivity of pastures, but may also decrease their quality. Increases in atmospheric CO_2 can increase the productivity of plants on which livestock feed. However, the quality of some of the forage found in pasturelands decreases with higher CO_2. As a result, cattle would need to eat more to get the same nutritional benefits.

Impacts on Fisheries

American fishermen catch or harvest five million metric tons of fish and shellfish each year. U.S. fisheries contribute more than $1.55 billion to the economy annually (as of 2012). Many fisheries already face multiple stresses, including overfishing and water pollution. Climate change may worsen these stresses. In particular, temperature changes could lead to significant impacts.

The ranges of many fish and shellfish species may change. In waters off the northeastern United States, several economically important species have shifted northward since the late 1960s. The three species shown in [the figure to the right] (American lobster, red hake, and black sea bass) have moved northward by an average of 119 miles.



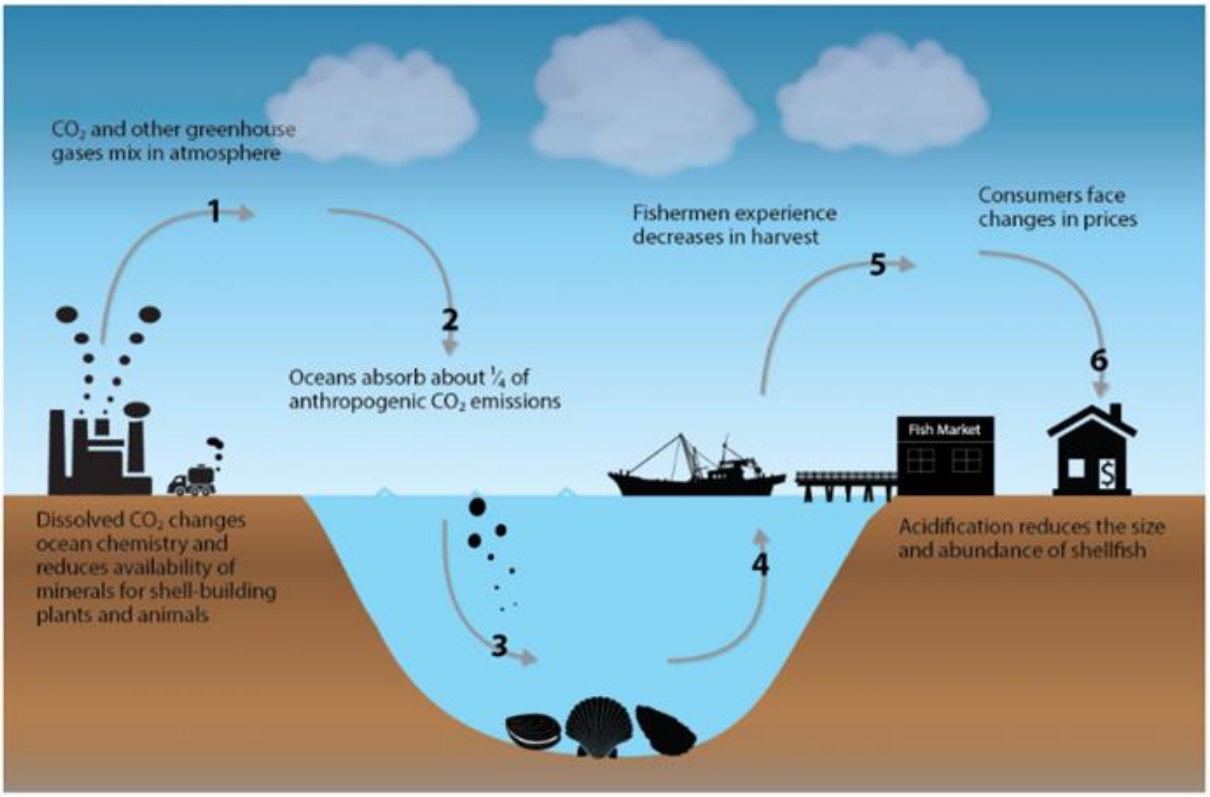
This map shows the annual centers of biomass for three species in the northeastern United States from 1968 to 2015. Dots are shaded from light to dark to show change over time. Source: US EPA (2016). *Climate Change Indicators in the United States: Marine Species Distribution*. Data Source: NOAA (2016). OceanAdapt.Exit

Many aquatic species can find colder areas of streams and lakes or move north along the coast or in the ocean. Nevertheless, moving into new areas may put these species into competition with other species over food and other resources, as explained on the Ecosystems Impacts page.

- Some marine disease outbreaks have been linked with changing climate. Higher water temperatures and higher estuarine salinities have enabled an oyster parasite to spread farther north along the Atlantic coast. Winter warming in the Arctic is contributing to salmon diseases in the Bering Sea and a resulting reduction in the Yukon Chinook Salmon, Finally, warmer temperatures have caused disease outbreaks in coral, eelgrass, and abalone.
- Changes in temperature and seasons can affect the timing of reproduction and migration. Many steps within an aquatic animal's lifecycle are controlled by temperature and the changing of the seasons. For example, in the Northwest warmer water temperatures may affect the lifecycle of salmon and increase the likelihood of disease. Combined with other climate impacts, these effects are projected to lead to large declines in salmon populations.

In addition to warming, the world's oceans are gradually becoming more acidic due to increases in atmospheric carbon dioxide (CO_2). Increasing acidity could harm shellfish by weakening their shells, which are created by removing calcium from seawater Acidification also threatens the structures of sensitive ecosystems upon which some fish and shellfish rely.

Figure 1. Ocean Acidification Impact Pathway for Shellfish



This diagram shows the impact pathway of carbon dioxide emissions on the shellfish market. Carbon dioxide is absorbed by oceans, resulting in ocean acidification. Acidification reduces the size and abundance of shellfish, which in turn leads to decreased harvest and eventually to changes in prices for consumers. Source: US EPA (2015). *Climate Change in the United States: Benefits of Global Action*

International Impacts

Climate change is very likely to affect food security at the global, regional, and local level. Climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity. Increases in the frequency and severity extreme weather events can also interrupt food delivery, and resulting spikes in food prices after extreme events are expected to be more frequent in the future. Increasing temperatures can contribute to spoilage and contamination.

Internationally, these effects of climate change on agriculture and food supply are likely to be similar to those seen in the United States. However, other stressors such as population growth may magnify the effects of climate change on food security. In developing countries, adaptation options like changes in crop-management or ranching practices, or improvements to irrigation are more limited than in the United States and other industrialized nations.

Any climate-related disturbance to food distribution and transport, internationally or domestically, may have significant impacts not only on safety and quality but also on food access. For example, the food transportation system in the United States frequently moves large volumes of grain by water. In the case of an extreme weather event affecting a waterway, there are few, if any, alternate pathways for transport. High temperatures and a shortage of rain in the summer of 2012 led to one of the most severe summer droughts the nation has seen and posed serious impacts to the Mississippi River watershed, a major transcontinental shipping route for Midwestern agriculture. This drought resulted in significant food and economic losses due to reductions in barge traffic, the volume of goods carried, and the number of Americans employed by the tugboat industry. The 2012 drought was immediately followed by flooding throughout the Mississippi in the spring of 2013, which also resulted

in disruptions of barge traffic and food transport. Transportation changes such as these reduce the ability of farmers to export their grains to international markets, and can affect global food prices.

Impacts to the global food supply concern the United States because food shortages can cause humanitarian crises and national security concerns. They also can increase domestic food prices.

http://huntingdoncd.org/agricultural-programs/extreme-weather

Agriculture – Extreme Weather Resilience

Overall ways to think about making changes

"No regrets" decisions: Make changes that result in a wide variety of benefits under multiple scenarios and have little or no risk.

Triage: Prioritize changing the most vulnerable aspects of your farm and make changes that are most likely to show results.

Overall good practices for farm resilience:

- Diversify your crops and species for redundancy in case one crop fails. Expand farm production to include a greater number of annual crops, perennial fruits or nuts, timber or other forest products, livestock, or other commodities (may or may not include agroforestry approaches). Use crop types that are different in plant type, structure and lifespan so one catastrophic event is less likely to mean failure for all fields.
- Improve soil structure and biology: it improves drainage, nutrient retention and water retention.
- Keep the soil covered year round with living crops and dead residues. Cover crops actually store more net carbon than transitioning to no-till does.
- Support mitigation: Many worthwhile adaptations also reduce fuel use or sequester carbon. Win-win for the environment! Examples: anything that sequesters carbon, reduces nitrogen gases, lowers energy use on farm.
- Choose varieties and breeds suited for the less predictable weather coming
- Add additional farming activities or new commodities to diversify farm products and revenue. Consider collaborating with other managers to diversify without increasing your workload.
- Make decisions that reduce exposure to climate risks – what's the more resilient option?

Problem: Extreme rain events

Rain events physically remove soil, leach nutrients, and drown low-lying fields.

Solutions

- Reduce nutrient loss leaching: don't over apply nutrients and switch to stable sources of nitrogen that slow-release, ones that are linked to organic matter.

Improve water infiltration:

- Make your soil a sponge, not a tarmac! This will reduce soil loss from erosion and instead allow the water to infiltrate rapidly.
- Improve soil structure through cover crops, no till farming, and by increasing organic matter content.
- Control vehicle traffic to minimize soil compaction by equipment.
- Keep the soil covered year round to reduce soil and nutrient loss from erosion:
- Manage cover crops so they provide cover during the vulnerable times of the year:
  - Interseeding for immediate post-harvest cover
  - Planting green for continuous spring cover
  - Use short term cover crops for 45-60 day windows: buckwheat, cowpea, soybean, millet, mustard, and oats.

- Maintain dead residue on the field.
- Adopt flood-tolerant crop varieties or varieties more resistant to higher peak flows and runoff velocities.

Farm layout changes:

- Maintain or improve infrastructure (waterways, lanes, roads, culverts, ponds, waste storage facilities, roofs and covers, roof runoff structures, heavy use areas, etc.) to accommodate more intense rain events.
- If something's been damaged by waterflow in the past, expect it to happen again.
  - Reshape damaged areas prior to replanting.
  - Remove problem areas from agricultural production, or convert them to perennial crops (grass, shrub, or tree crops); pasture/grazing lands, forest cover, or conservation buffers suitable to conveying water.
- Buy or lease new acreage with good drainage.
- Match crops to the most appropriate areas on the farm for their water tolerance.

Problem: Increased temperatures and crop heat stress

Many common crops of the Northeast are not well suited for the warming trends predicted for this century – especially crops that require long chill periods for optimum growth. Heat stress at the wrong time can stunt growth and lower nitrogen uptake efficiency.

Warmer nighttime temperatures during hot spells also can reduce crop yields. Crops grown in areas with a warmer average nighttime temperature may be less sweet due to increased respiration where the plant taps stored sugar for energy

Solutions

- Capitalize on the longer growing season with crops that do well in the heat, or double-cropping to offset potential lower production due to heat stress.
- Plant cover crops: living *and* dead cover will reflect heat away from the soil whereas bare soil will absorb it. The cover will also conserve soil moisture.
- Especially for high-value crops, match the correct crop to the correct localized climate on the farm. Where is it hottest? Coolest?
- Shift planting dates to avoid heat stress during critical periods of plant development. Consider changing the rates and timing of hay harvesting as well.
- Shift crops to types that can be grown in a controlled environment, using hoop and high tunnel houses or greenhouses.

Problem: Increased temperatures change insect and weed pressure.

Heat stress and new frost patterns change insect and weed pressure.

A longer growing season means more insect generations per season, requiring increased intensity of management. Warmer weather and increasing concentrations of carbon dioxide in the atmosphere favor weed growth over crop plants in many cases.

Solutions

- Use crop varieties and species resistant to pests and diseases.

- Increase the diversity in your crop rotation as well as the length. Vary the duration of crops by integrating perennials into the rotation. These help break pest and weed cycles.
- Scout your fields for weeds and pests more frequently to prevent the escalation of an infestation.
- Remove or prevent establishment of invasive plants and other competitors following soil disturbance or land clearing.
- Improve your use of seasonal and short-term weather forecasts. Increases in temperature and humidity may also alter the disease complex for crops.
- Use integrated pest management (IPM) strategies (prevention, avoidance, monitoring, and suppression) to increase the long-term effectiveness of your pest management program.
- Improved rapid response plans and regional monitoring efforts will allow for targeted control of new weeds and pests before they become established.
- Harvest early.
- Create habitat and refugia for pollinators or other beneficial organisms. One way to do this is to plant a strip of plants that attract beneficials along the edge of a field. Another way is to reinvigorate existing woodland and natural areas to make them more attractive to target species.

Problem: Heat stress affecting livestock and pastures

Heat stress associated with hotter summers will create dangerous and unhealthy conditions for livestock. Heat stress can reduce egg, meat and milk productivity and reproductive capacity. Dairy milk production begins to be affected at 68°F with moderate levels of humidity. Increased nighttime temperatures also can increase livestock stress. Young stock can be more vulnerable to heat stress. Availability and cost of animal feed will fluctuate as climate affects crops like corn grain and silage, and pasture forage. Cool season pastures could suffer a longer and more intense “summer slump.”

Solutions

Management changes

- Use grass or fodder banks (resting of pastures for >1 year) to provide forage during dry periods.
- Integrate livestock into your cropping systems to access additional forage, reduce feed costs, eliminate manure concentration areas, or improve overall farm efficiency. Let them utilize crop residues or cover crops. This can also stimulate soil biology.
- Alter mix of grazing species. Plant multi-species pasture mixtures including species adapted to warmer or drier climates. Plant warm-season annual forages with good heat tolerance (millet, sorghum, sorghum-sudangrass, cowpea, sunn hemp, etc.) to complement cool season pastures during the summer slump.
- Increase available shade for pastured animals.
- Be prepared to alter livestock stocking rates and alter their access to pasture based on forage availability.
- Adjust animals’ diet (more fat, less protein).
- Feed animals during the cool parts of the day. Feeding raises body temperature, so feeding in the hottest part of the day increases risk of heat stress associated with digestion. Move cattle to fresh pastures at night.

Stock

- Switch to or incorporate alternative livestock breeds, class, or species, especially those with a higher heat, drought, and parasite tolerance.
- Diversify animal products or ages, such as including both cow-calves and yearlings.
- Alter the timing or placement of feeder animals and subsequent finishing time of these animals to reduce stress associated with heat waves.
- Alter the timing of animal reproduction to match suitable temperatures and feed availability. This could be on an annual basis or even the time of day you choose to breed animals.
- Monitor animals to catch early warning signs of stress.

Structural: When it's time for barn expansion or renovation…

- House livestock in structures such as open pole barns equipped with evaporative cooling techniques that are not energy intensive or require expensive technology.
- Enhance energy efficiency in facilities using light-emitting diode (LED) lights or other lighting that produces less heat.
- Insulate under barn roofs to buffer extreme heat and save on cooling costs.
- Build new barns with adequate cooling capacity for future heat loads. Design and implement new housing for animal agriculture with consideration for heat waves and extreme rainfall events. Many NRCS designs are appropriate for 25-year storms.
- Improve climate control in facilities using fans, misters, soakers, and other features.
- Reduce over-crowding and improve barn ventilation.

Problem: Drought

Longer periods without rainfall can stress plants already burdened by other consequences of heat stress.

Solutions

- Improve soil structure to maintain a high soil water holding capacity by increasing organic matter and decreasing compaction and soil disturbance.
- Convert annual crops to perennial crops when possible.
- Employ alternative methods for crop and cover crop establishment in dry times, such as planting green. Retain cover crop residues during the growing system.
- Plan backup crops in case of failures, like harvesting cover crops as an emergency forage or for seed or grain.
- Shift to drought-tolerant and water efficient crop varieties. Sorghum silage is a more drought tolerant forage than corn silage. Plant earlier maturing varieties to avoid late-season drought stress
- Drought stress lowers nitrogen use efficiency. Increase the n-use efficiency of your system to compensate (make nitrogen available at the most critical periods in plant development, injecting manure). Account for residual nitrogen left in the soil after dry summers.
- Drill new wells and seek alternative water sources for vulnerable wells and springs. Increase available water for livestock.
- Consider alternate methods of harvesting water such as cisterns or catchment ponds.

- Prepare for the need to irrigate for crops that have never needed it before. Think about increasing your irrigation capacity, particularly for high-value crops.
- Improve irrigation efficiency. Use new technology for subsurface irrigation, and irrigate with gray or reclaimed water to reduce water use.

https://www.ucsusa.org/food_and_agriculture/solutions/expand-healthy-food-access/local-and-regional-food-101.html#.W6T-Z_ZFyM8

Local and Regional Food Systems 101

Local and regional food systems are experiencing rapid growth in the U.S. With a little help from forward-looking public policy, they will continue growing, benefiting their customers, their local economies, and the nation's public health and environmental goals.

But what are they, exactly? Defining “local” is challenging, so here we focus on markets in which farmers sell food directly to a consumer or institution. We've put together a quick primer on some of the most common ways in which farmers sell their food directly to customers, bypassing mainstream, consolidated distribution and retailing systems.

Farmers Markets allow individual farmers and other vendors to market their products directly to consumers in a single location, giving shoppers their choice from a variety of fresh, local food. Frequently they occur in an outdoor public venue at specified times during the growing season. Farmers markets were once common in the U.S., but the rise of supermarkets and improvements in highway transportation led to their decline, and by 1970 there were just 340 farmers markets left in the country. In recent decades, farmers markets have made a dramatic comeback, and by 2011 their numbers had grown to over 7,000.

Community Supported Agriculture (CSA) is a system in which consumers buy a share of a farm's output at the beginning of the year and receive weekly installments of food throughout the growing season. This arrangement helps farmers by providing an infusion of cash early in the year and by allowing them to spend less time on marketing once the growing season begins. Benefits to consumers include the opportunity to support and interact with a local farmer and to receive fresh produce. According to one recent estimate, there are currently over 4,000 CSAs operating in the U.S.

Farm-to-School programs aim to improve the nutrition of school children by adding fresh, local food to cafeteria menus, to enrich their education through curriculum development and experiential learning opportunities, and to foster connections between local farms and communities. Similar models in other

institutional markets—such as hospitals, prisons, and military installations—are also attracting growing interest.

Food Hubs are distribution centers that provide a logistical and marketing interface between farmers and regional buyers. Farmers deliver their products to the food hub, which provides storage, processing, and packaging services and markets the food to wholesale buyers such as restaurants, hotels, and universities, as well as retail customers. These facilities make it easier for local and regional farmers to compete with the mainstream, consolidated food production and distribution system.

Roadside Stands have long been a familiar fixture along secondary roads in rural areas. They provide farmers with the most convenient marketing channel imaginable (the food never has to leave the premises), while attracting customers with the promise of maximum freshness.

U-Pick Operations, like roadside stands, rely on bringing the customer to the farm. They differ in allowing the customer to go into the fields or orchards to harvest the food themselves. For many customers, there is a strong appeal in the idea of getting their food directly from the field it was grown in.

https://www.gps.gov/applications/agriculture/

Precision Agriculture

The development and implementation of precision agriculture or site-specific farming has been made possible by combining the Global Positioning System (GPS) and geographic information systems (GIS). These technologies enable the coupling of real-time data collection with accurate position information, leading to the efficient manipulation and analysis of large amounts of geospatial data. GPS-based applications in precision farming are being used for farm planning, field mapping, soil sampling, tractor guidance, crop scouting, variable rate applications, and yield mapping. GPS allows farmers to work during low visibility field conditions such as rain, dust, fog, and darkness.

In the past, it was difficult for farmers to correlate production techniques and crop yields with land variability. This limited their ability to develop the most effective soil/plant treatment strategies that could have enhanced their production. Today, more precise application of pesticides, herbicides, and fertilizers, and better control of the dispersion of those chemicals are possible through precision agriculture, thus reducing expenses, producing a higher yield, and creating a more environmentally friendly farm.

Precision agriculture is now changing the way farmers and agribusinesses view the land from which they reap their profits. Precision agriculture is about collecting timely geospatial information on soil-plant-animal requirements and prescribing and applying site-specific treatments to increase agricultural production and protect the environment. Where farmers may have once treated their fields uniformly, they are now seeing benefits from micromanaging their fields. Precision agriculture is gaining in popularity largely due to the introduction of high technology tools into the agricultural community that are more accurate, cost effective, and user friendly. Many of the new innovations rely on the integration of on-board computers, data collection sensors, and GPS time and position reference systems.

Many believe that the benefits of precision agriculture can only be realized on large farms with huge capital investments and experience with information technologies. Such is not the case. There are inexpensive and easy-to-use methods and techniques that can be developed for use by all farmers. Through the use of GPS, GIS, and remote sensing, information needed for improving land and water use can be collected. Farmers can achieve additional benefits by combining better utilization of fertilizers and other soil amendments, determining the economic threshold for treating pest and weed infestations, and protecting the natural resources for future use.

GPS equipment manufacturers have developed several tools to help farmers and agribusinesses become more productive and efficient in their precision farming activities. Today, many farmers use GPS-derived products to enhance operations in their farming businesses. Location information is collected by GPS receivers for mapping field boundaries, roads, irrigation systems, and problem areas in crops such as weeds or disease. The accuracy of GPS allows farmers to create farm maps with precise acreage for field areas, road locations and distances between points of interest. GPS allows farmers to accurately

navigate to specific locations in the field, year after year, to collect soil samples or monitor crop conditions.

Crop advisors use rugged data collection devices with GPS for accurate positioning to map pest, insect, and weed infestations in the field. Pest problem areas in crops can be pinpointed and mapped for future management decisions and input recommendations. The same field data can also be used by aircraft sprayers, enabling accurate swathing of fields without use of human “flaggers” to guide them. Crop dusters equipped with GPS are able to fly accurate swaths over the field, applying chemicals only where needed, minimizing chemical drift, reducing the amount of chemicals needed, thereby benefiting the environment. GPS also allows pilots to provide farmers with accurate maps.

Farmers and agriculture service providers can expect even further improvements as GPS continues to modernize. In addition to the current civilian service provided by GPS, the United States is committed to implementing a second and a third civil signal on GPS satellites. The first satellite with the second civilian signal was launched in 2005. The new signals will enhance both the quality and efficiency of agricultural operations in the future.

Benefits

- Precision soil sampling, data collection, and data analysis, enable localized variation of chemical applications and planting density to suit specific areas of the field.
- Accurate field navigation minimizes redundant applications and skipped areas, and enables maximum ground coverage in the shortest possible time.
- Ability to work through low visibility field conditions such as rain, dust, fog and darkness increases productivity.
- Accurately monitored yield data enables future site-specific field preparation.
- Elimination of the need for human "flaggers" increases spray efficiency and minimizes over-spray.

http://www.thedrive.com/tech/18456/drones-in-agriculture-how-uavs-make-farming-more-efficient

Ag Technology

How are drones used in Agriculture?

Mapping/Surveying

Drones equipped with near infrared camera sensors allow the drone to see the spectrum of light that plants use to absorb light for photosynthesis. From this information, using the normalized difference vegetation index (NDVI) farmers can understand plant health. Software analysis can be used to change values in order to reflect the specific crop type and even in which state of life a specific crop is in. In addition to crop health, drones can create detailed GPS maps of the crop field area. This allows farmers to better plan where crops are being planted to maximize land, water and fertilizer usage.

Crop Dusting/Spraying

To maintain yields, crops require proper fertilization and pesticide application. Manually driving a vehicle through the field to spray or crop dust by manned airplane to spray are methods of the past. Crop spraying drones can carry large liquid storage reservoirs, can be operated more safely (even autonomously), and can be operated and maintained at a fraction of the cost compared to crop dusters.

Irrigation Management

Drones equipped with thermal cameras can provide excellent insight into irrigation by highlighting areas that have pooling water or insufficient soil moisture. These issues can severely affect crop yields and quality. Thermal drones give farmers a better way to understand their fields through more frequent inspections and surveying.

Livestock Monitoring

Drones with thermal imaging cameras allow a single remote pilot in command to monitor livestock. The operator can check in on the herd to see if there are any injured, missing, or birthing animals. Drones give livestock farmers a new way to keep an eye on their livestock at all times resulting greater profits.

The benefits of using drones in Farming

Increase Yields

Improve production, efficiency, and get higher yields by identifying problems before they happen with increased crop health awareness and frequency.

Save Time

Drones can be set up and deployed quickly. This ease of use allows farmers to gain information routinely or whenever they need it.

Plan for the Future

Generate precision orthomosaic maps for better crop planning and land management. (Orthomosaic maps are a grouping of many overlapping images of a defined area which are processed to create a new, larger "orthomosaic." Ortho maps can help farmers get insights into how their crops are doing, and also allow for keeping a highly accurate record of the crops on a piece of land over time.

https://www.nature.com/scitable/knowledge/library/history-of-agricultural-biotechnology-how-crop-development-25885295

Biotechnology

History of Agricultural Biotechnology: How Crop Development has Evolved

By: Wieczorek Ania (Dept of Tropical Plant and Soil Sciences, University of Hi at Manoa) & Wright Mark (Dept of Plant and Env Protection Sciences, University of Hi at Manoa)

Citation: Wieczorek, A. M. & Wright, M. G. (2012) History of Agricultural Biotechnology: How Crop Development has Evolved. Nature Education Knowledge 3(10):9

Have you ever wondered where our agricultural crops come from? And what were they like thousands of years ago, or hundreds of years ago? Our food crops today are in fact very different from the original wild plants from which they were derived.

About 10,000 years BC, people harvested their food from the natural biological diversity that surrounded them, and eventually domesticated crops and animals. During the process of domestication, people began to select better plant materials for propagation and animals for breeding, initially unwittingly, but ultimately with the intention of developing improved food crops and livestock. Over thousands of years farmers selected for desirable traits in crops, and thus improved the plants for agricultural purposes. Desirable traits included crop varieties (also known as cultivars, from "cultivated varieties") with shortened growing seasons, increased resistance to diseases and pests, larger seeds and fruits, nutritional content, shelf life, and better adaptation to diverse ecological conditions under which crops were grown.

Over the centuries, agricultural technology developed a broad spectrum of options for food, feed, and fiber production. In many ways, technology reduces the amount of time we dedicate to basic activities like food production, and makes our lives easier and more enjoyable. Everyone is familiar with how transportation has changed over time to be more efficient and safer (Figure 1). Agriculture has also undergone tremendous changes, many of which have made food and fiber production more efficient and safer (Figure 1). For example in 1870, the total population of the USA was 38,558,371 and 53% of this population was involved in farming; in 2000, the total population was 275,000,000 and only 1.8% of the population was involved in farming. There are negative aspects to having so few members of society involved in agriculture, but this serves to illustrate how technological developments have reduced the need for basic farm labor.

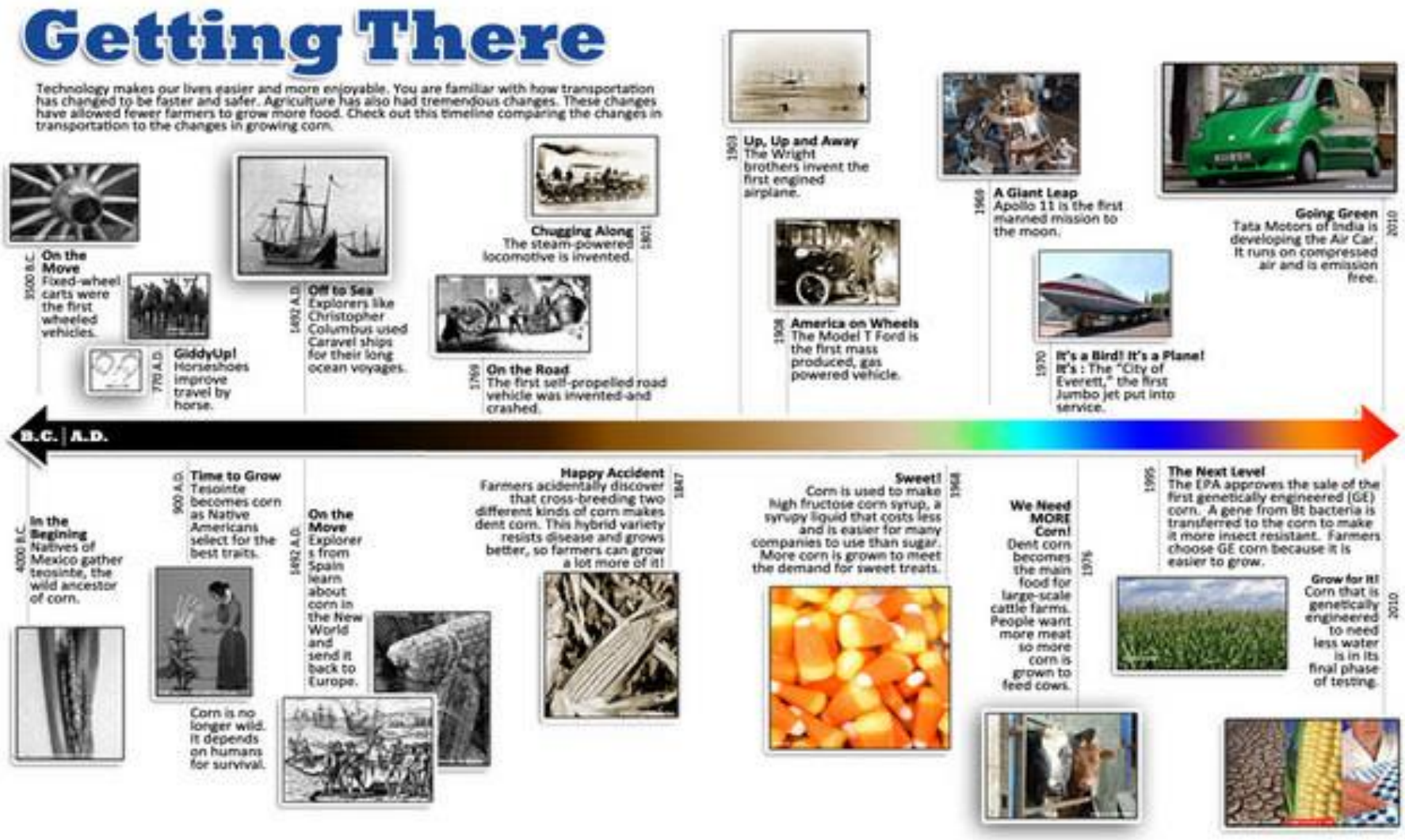


Figure 1: A timeline showing how human transportation systems have evolved, from primitive, slow, and inefficient vehicles, to modern, faster, and more efficient options. Corresponding advances in agricultural biotechnology are shown below, similarly illustrating how advances changed our ability to develop new agricultural crops.

This article concentrates on how scientific discoveries and technological developments have allowed us to improve crop development in agriculture. Most people do not realize that among early agriculture developments, really at the genesis of agricultural technology, the ancient Egyptians made wine and made rising dough for bread, using fermentation. A significant event in the development of agriculture occurred in 1492 with the introduction of corn, native to the Americas, to the rest of the world, and European growers adapted the plant to their unique growing conditions. At this stage of history, crops were being transported around the world and grown under a diversity of conditions.

Agriculturalists started conducting selective breeding of crops before having a thorough understanding of the basis of genetics. Gregor Mendel's discoveries explaining how traits pass from parents to offspring shed new light on the matter. Mendel's work showed that genes separate during the formation of gametes, and unite randomly during fertilization; he also showed that genes are transmitted independently of one another to offspring. This understanding of the way that plants and animals acquire traits form parents created the potential for people to selectively breed crops and livestock. Gregor Mendel's discovery revolutionized agriculture by launching the development of selective cross breeding with a comprehensive understanding of the underlying mechanisms of inheritance.

Classical Breeding with Induced Mutation

Mutations (Figure 2) are changes in the genetic makeup of a plant. Mutations occur naturally and sometimes result in the development of new beneficial traits. In 1940, plant breeders learned that they could make mutations happen faster with a process called mutagenesis. Radiation or chemicals are used to change the plant's DNA, the basic molecular system of all organisms' genetic material. The goal is to cause changes in the sequence of the base pairs of DNA, which provide biochemical instructions for the development of plants. Resultant plants may possess new and desirable characteristics through this modification of their genetic material. During this process, plant breeders must grow and evaluate each plant from each seed produced.

Figure 2: The effects of genetic mutations in carrots.

More than 2,500 plant varieties (including rice, wheat, grapefruit, lettuce and many fruits) have been developed using radiation mutagenesis (FAO/IAEA, 2008). Induced mutation breeding was widely used in the United States during the 1970's, but today few varieties are produced using this technique. As our understanding of genetics developed, so new technologies for plant variety development arose. Examples of these that are used today include genetic marker assisted breeding, where molecular markers associated with specific traits could be used to direct breeding programs, and genetic engineering. Some of the significant steps leading to the current state of the art are explained below.

1. Discovery by Watson and Crick: structure of DNA, 1953: Another milestone in the development of understanding of genetics and how genes function, was the discovery of the structure of DNA (the basis of genes), and how DNA works. Two scientists, James Watson and Francis Crick made this discovery (Pray 2008), considered to be one of the most significant scientific works in biology, largely through synthesis of the work of other scientists. Their work contributed significantly to understanding what genes were.

2. Discovering genes that move (transposons): Transposons are sections of DNA-genes-that move from one location to another on a chromosome. Transposons have been referred to as "jumping genes", genes that are able to move around. Interestingly, transposons may be manipulated to alter the DNA inside living organisms. Barbara McLintock (1950) discovered an interesting effect of transposons. She was able to show how the changes in DNA caused by transposons affected the color of maize kernels.

3. Tissue culture and plant regeneration: Another significant development in technology that was important for plant breeding was the development of micropropagation techniques, known as tissue culture (Thorpe 2007). Tissue culture permits researchers to clone plant material by excising small amounts of tissue from plants of interest, and then inducing growth of the tissue on media, to ultimately form a new plant. This new plant carries the entire genetic information of the donor plant. Exact copies of a desired plant could thus be produced without depending on pollinators, the need for seeds, and this could all be done quickly.

4. Embryo rescue: Often when distantly related plant species are hybridized are crossed, the embryos formed following fertilization will be aborted. The development of embryo rescue technology permitted crop breeders to make crosses among distantly related varieties, and then to save the resulting embryos and then grow them into whole plants through tissue culture.

5. Protoplast fusion: Protoplasts are cells that have lost their cell walls. The cell wall can be removed either by mechanical means, or by the action of enzymes. They are left with only a cell membrane surrounding the cell. Protoplasts can be manipulated in many ways that can be used in plant breeding. This includes producing hybrid cells (by means of cell fusion) and using protoplasts to introduce new genes into plant cells, which can then be grown using tissue culture techniques (Thorpe 2007).

6. Genetic engineering: Building on the above discoveries into the 1980s, advances in the field of molecular biology provided scientists with the potential to purposefully transfer DNA between organisms, whether closely or distantly related. This set the stage for potentially extremely beneficial advancement in crop breeding, but has also been very controversial.

Genetic Engineering of Organisms

The basic structure of DNA is identical in all living things. In all organisms, different characteristics are determined by the sequence of the DNA base pairs. Biotechnology has developed to the point where researchers can take one or more specific genes from nearly any organism, including plants, animals, bacteria, or viruses, and introduce those genes into the genome of another organism. This is called recombinant DNA technology (Watson et al. 1992). In 1978, the first commercial product arising from the use of recombinant DNA technology gene transfer was synthetic insulin. Pig and cattle pancreatic glands were previously the only way of producing insulin for human use. In 1988, chymosin (known as Rennin) was the first enzyme produced from a genetically modified source-yeast-to be approved for use in food. Previously this enzyme for cheese production was obtained from cows' stomach linings.

In agricultural biotechnology, changes are made directly to the plant's genome. Once the gene that determines a desirable trait is identified, it can be selected, extracted, and transferred directly into another plant genome. Plants that have genes from other organisms are referred to as transgenic. The presence of the desired gene, controlling the trait, can be tested for at any stage of growth, such as in small seedlings in a greenhouse tray. A breeder can thus quickly evaluate the plants that are produced and then select those that best express the desired trait. Producing new varieties of crops through genetic engineering takes about 10 years on average.

The applications of genetic engineering through recombinant DNA technology increased with time, and the first small scale field trials of genetically engineered plant varieties were planted and in the USA and Canada in 1990, followed by the first commercial release of genetically engineered crops in 1992. Since that time, adoption of genetic engineered plants by farmers has increased annually. While the benefits of genetically engineered crop varieties have been widely recognized, there has been extensive opposition to this technology, from environmental perspectives, because of ethics considerations, and people concerned with corporate control of crop varieties.

Comparing Classical Breeding and Crop Breeding Through Genetic Engineering

Crops produced through genetic engineering are sometimes referred to as genetically modified organisms. The term genetic modification and so-called genetically modified organisms (GMOs) is frequently misused. All types (organic, conventional) of agriculture modify the genes of plants so that they will have desirable traits. The difference is that traditional forms of breeding change the plant's genetics indirectly by selecting plants with specific traits, while genetic engineering changes the traits by making changes directly to the DNA. In traditional breeding, crosses are made in a relatively uncontrolled manner. The breeder chooses the parents to cross, but at the genetic level, the results are unpredictable. DNA from the parents recombines randomly. In contrast, genetic engineering permits highly targeted transfer of genes, quick and efficient tracking of genes in new varieties, and ultimately increased efficiency in developing new crop varieties with new and desirable traits.

Conclusions: Technology, Progress, Opposition, and Risk Assessment

Many different tools are available for increasing and improving agricultural production. These tools include methods to develop new varieties such as classical breeding and biotechnology. Traditional

agricultural approaches are experiencing some resurgence today, with renewed interest in organic agriculture; an approach that does not embrace the use of genetically engineered crops. The role that genetic engineering stands to play in sustainable agricultural development is an interesting topic for the future.

As with the development of any new technology there are concerns about associated risks, and agricultural biotechnology is no exception. All crops developed using genetic engineering are subjected to extensive safety testing before being released for commercial use. Risk assessments are conducted for these new varieties, and only those that are safe for human use are released. Some concerns arise through people not fully understanding the reporting of risk. Many consider any level of risk unacceptable. Some prefer the application of the precautionary principle when releasing new technology, but this is not a realistic interpretation of what risk assessments tell us (See information presented by Land Grant Universities of the USA).

Extensive risk assessment and safety testing of crops developed through the use of genetic engineering has shown that there are no varieties in use that pose risks to consumers. This is not to say that new varieties should not be carefully examined for safety; each case should be considered on its unique merits.

https://www.usda.gov/topics/biotechnology/biotechnology-frequently-asked-questions-faqs

Biotechnology Frequently Asked Questions (FAQs)

1. What is Agricultural Biotechnology?

Agricultural biotechnology is a range of tools, including traditional breeding techniques, that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses. Modern biotechnology today includes the tools of genetic engineering.

2. How is Agricultural Biotechnology being used?

Biotechnology provides farmers with tools that can make production cheaper and more manageable. For example, some biotechnology crops can be engineered to tolerate specific herbicides, which make weed control simpler and more efficient. Other crops have been engineered to be resistant to specific plant diseases and insect pests, which can make pest control more reliable and effective, and/or can decrease the use of synthetic pesticides. These crop production options can help countries keep pace with demands for food while reducing production costs. A number of biotechnology-derived crops that have been deregulated by the USDA and reviewed for food safety by the Food and Drug Administration (FDA) and/or the Environmental Protection Agency (EPA) have been adopted by growers.

Many other types of crops are now in the research and development stages. While it is not possible to know exactly which will come to fruition, certainly biotechnology will have highly varied uses for agriculture in the future. Advances in biotechnology may provide consumers with foods that are nutritionally-enriched or longer-lasting, or that contain lower levels of certain naturally occurring toxicants present in some food plants. Developers are using biotechnology to try to reduce saturated fats in cooking oils, reduce allergens in foods, and increase disease-fighting nutrients in foods. They are also researching ways to use genetically engineered crops in the production of new medicines, which may lead to a new plant-made pharmaceutical industry that could reduce the costs of production using a sustainable resource.

Genetically engineered plants are also being developed for a purpose known as phytoremediation in which the plants detoxify pollutants in the soil or absorb and accumulate polluting substances out of the soil so that the plants may be harvested and disposed of safely. In either case the result is improved soil quality at a polluted site. Biotechnology may also be used to conserve natural resources, enable animals to more effectively use nutrients present in feed, decrease nutrient runoff into rivers and bays, and help meet the increasing world food and land demands. Researchers are at work to produce hardier crops that will flourish in even the harshest environments and that will require less fuel, labor, fertilizer, and water, helping to decrease the pressures on land and wildlife habitats.

In addition to genetically engineered crops, biotechnology has helped make other improvements in agriculture not involving plants. Examples of such advances include making antibiotic production more efficient through microbial fermentation and producing new animal vaccines through genetic engineering for diseases such as foot and mouth disease and rabies.

3. What are the benefits of Agricultural Biotechnology?

The application of biotechnology in agriculture has resulted in benefits to farmers, producers, and consumers. Biotechnology has helped to make both insect pest control and weed management safer and easier while safeguarding crops against disease.

For example, genetically engineered insect-resistant cotton has allowed for a significant reduction in the use of persistent, synthetic pesticides that may contaminate groundwater and the environment.

In terms of improved weed control, herbicide-tolerant soybeans, cotton, and corn enable the use of reduced-risk herbicides that break down more quickly in soil and are non-toxic to wildlife and humans. Herbicide-tolerant crops are particularly compatible with no-till or reduced tillage agriculture systems that help preserve topsoil from erosion.

Agricultural biotechnology has been used to protect crops from devastating diseases. The papaya ringspot virus threatened to derail the Hawaiian papaya industry until papayas resistant to the disease were developed through genetic engineering. This saved the U.S. papaya industry. Research on potatoes, squash, tomatoes, and other crops continues in a similar manner to provide resistance to viral diseases that otherwise are very difficult to control.

Biotech crops can make farming more profitable by increasing crop quality and may in some cases increase yields. The use of some of these crops can simplify work and improve safety for farmers. This allows farmers to spend less of their time managing their crops and more time on other profitable activities.

Biotech crops may provide enhanced quality traits such as increased levels of beta-carotene in rice to aid in reducing vitamin A deficiencies and improved oil compositions in canola, soybean, and corn. Crops with the ability to grow in salty soils or better withstand drought conditions are also in the works and the first such products are just entering the marketplace. Such innovations may be increasingly important in adapting to or in some cases helping to mitigate the effects of climate change.

The tools of agricultural biotechnology have been invaluable for researchers in helping to understand the basic biology of living organisms. For example, scientists have identified the complete genetic structure of several strains of Listeria and Campylobacter, the bacteria often responsible for major outbreaks of food-borne illness in people. This genetic information is providing a wealth of opportunities that help researchers improve the safety of our food supply. The tools of biotechnology have "unlocked doors" and are also helping in the development of improved animal and plant varieties, both those produced by conventional means as well as those produced through genetic engineering.

4. What are the safety considerations with Agricultural Biotechnology?

Breeders have been evaluating new products developed through agricultural biotechnology for centuries. In addition to these efforts, the United States Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA) work to ensure that crops produced through genetic engineering for commercial use are properly tested and studied to make sure they pose no significant risk to consumers or the environment.

Crops produced through genetic engineering are the only ones formally reviewed to assess the potential for transfer of novel traits to wild relatives. When new traits are genetically engineered into a crop, the new plants are evaluated to ensure that they do not have characteristics of weeds. Where biotech crops

are grown in proximity to related plants, the potential for the two plants to exchange traits via pollen must be evaluated before release. Crop plants of all kinds can exchange traits with their close wild relatives (which may be weeds or wildflowers) when they are in proximity. In the case of biotech-derived crops, the EPA and USDA perform risk assessments to evaluate this possibility and minimize potential harmful consequences, if any.

Other potential risks considered in the assessment of genetically engineered organisms include any environmental effects on birds, mammals, insects, worms, and other organisms, especially in the case of insect or disease resistance traits. This is why the USDA's Animal and Plant Health Inspection Service (APHIS) and the EPA review any environmental impacts of such pest-resistant biotechnology derived crops prior to approval of field-testing and commercial release. Testing on many types of organisms such as honeybees, other beneficial insects, earthworms, and fish is performed to ensure that there are no unintended consequences associated with these crops.

With respect to food safety, when new traits introduced to biotech-derived plants are examined by the EPA and the FDA, the proteins produced by these traits are studied for their potential toxicity and potential to cause an allergic response. Tests designed to examine the heat and digestive stability of these proteins, as well as their similarity to known allergenic proteins, are completed prior to entry into the food or feed supply. To put these considerations in perspective, it is useful to note that while the particular biotech traits being used are often new to crops in that they often do not come from plants (many are from bacteria and viruses), the same basic types of traits often can be found naturally in most plants. These basic traits, like insect and disease resistance, have allowed plants to survive and evolve over time.

5. How widely used are biotechnology crops?

According to the USDA's National Agricultural Statistics Service (NASS), biotechnology plantings as a percentage of total crop plantings in the United States in 2012 were about 88 percent for corn, 94 percent for cotton, and 93 percent for soybeans. NASS conducts an agricultural survey in all states in June of each year. The report issued from the survey contains a section specific to the major biotechnology derived field crops and provides additional detail on biotechnology plantings. The most recent report may be viewed at the following website: https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx

For a summary of these data, see the USDA Economic Research Service data feature at: https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx

The USDA does not maintain data on international usage of genetically engineered crops. The independent International Service for the Acquisition of Agri-biotech Applications (ISAAA), a not-for-profit organization, estimates that the global area of biotech crops for 2012 was 170.3 million hectares, grown by 17.3 million farmers in 28 countries, with an average annual growth in area cultivated of around 6 percent. More than 90 percent of farmers growing biotech crops are resource-poor farmers in developing countries. ISAAA reports various statistics on the global adoption and plantings of biotechnology derived crops. The ISAAA website is https://www.isaaa.org

6. What are the roles of government in agricultural biotechnology?

Please note: These descriptions are not a complete or thorough review of all the activities of these agencies with respect to agricultural biotechnology and are intended as general introductory materials only. For additional information please see the relevant agency websites.

Regulatory

The Federal Government developed a Coordinated Framework for the Regulation of Biotechnology in 1986 to provide for the regulatory oversight of organisms derived through genetic engineering. The three principal agencies that have provided primary guidance to the experimental testing, approval, and eventual commercial release of these organisms to date are the USDA's Animal and Plant Health Inspection Service (APHIS), the Environmental Protection Agency (EPA), and the Department of Health and Human Services' Food and Drug Administration (FDA). The approach taken in the Coordinated Framework is grounded in the judgment of the National Academy of Sciences that the potential risks associated with these organisms fall into the same general categories as those created by traditionally bred organisms.

Products are regulated according to their intended use, with some products being regulated under more than one agency. All government regulatory agencies have a responsibility to ensure that the implementation of regulatory decisions, including approval of field tests and eventual deregulation of approved biotech crops, does not adversely impact human health or the environment.

The Animal and Plant Health Inspection Service (APHIS) is responsible for protecting U.S. agriculture from pests and diseases. APHIS regulations provide procedures for obtaining a permit or for providing notification prior to "introducing" (the act of introducing includes any movement into or through the U.S., or release into the environment outside an area of physical confinement) a regulated article in the U.S. Regulated articles are organisms and products altered or produced through genetic engineering that are plant pests or for which there is reason to believe are plant pests.

The regulations also provide for a petition process for the determination of non-regulated status. Once a determination of non-regulated status has been made, the organism (and its offspring) no longer requires APHIS review for movement or release in the U.S.