Water Farming

MANAGING AGRICULTURAL LANDS FOR CLEAN & SAFE WATER

AARON DE LONG

Pasa SUSTAINABLE AGRICULTURE

Photo: Perennial agriculture ecosystem designed by Mark Shepard at New Forest Farm, Viola, Wisconsin. Credit: Google Earth

This booklet explores how agriculture has the potential to either degrade and deplete, or protect and enrich, our shared water resources.

By understanding the connections between specific farming practices and water quality and quantity, farmers, communities, and government agencies can more effectively work together to nurture a cleaner, more abundant water supply and a healthier, more secure food system.

While the geographic focus for this booklet is Pennsylvania, the core issues discussed—water, farming, and a sustainable future—are global.

The Challenge

Between 1970 and 2015, the world population nearly doubled. Over the same period, global grain production nearly tripled, livestock production more than tripled, and vegetable production increased fourfold.[1] This massive growth in agricultural yields—commonly known as the Green Revolution—was achieved primarily by farmers increasingly relying on chemical inputs, such as pesticides and fertilizers, as well as by expanding agricultural lands, often into ecologically-sensitive areas. The short-term profit and production returns on these practices have been dramatic, and a boon to many, but the long-term consequences on human and environmental health have proven to be substantial.

Poor soil health management practices, for instance—including overgrazing livestock on pasture and rangeland, excessive tillage, and expanding agricultural activity into marginal areas—have collectively increased soil erosion and an affiliated loading of sediments and nutrients into waterways. Sediments washed or blown away from farm fields not only typically remove the richest layers of topsoil, they often carry with them nutrients from historical manure and fertilizer applications. Excessive nutrients have given rise to algae blooms responsible for sometimes massive dead zones in lakes and bays, where oxygen levels are so low that most aquatic life either dies or leaves the area. In 2019, the dead zone in the Gulf of Mexico, largely fueled by nutrient runoff from farms, was estimated to encompass nearly 7,000 square miles.[2]

Pesticides developed to control weeds and pests over the last half century have had deleterious impacts on human health as well. Atrazine, for example, an herbicide widely used in agriculture for decades, has been found to persist in groundwater, migrate into public and private drinking water supplies, and has been linked to numerous human health issues, including heart, lung, and kidney damage.[3] Nitrate, a core component of many synthetic fertilizers, is now the most common contaminant in the world's groundwater aquifers and is also an established human health risk.[4]

In most high-income countries today, and many emerging economies, agricultural pollution has overtaken contamination from settlements and industries as the major factor in the degradation of inland and coastal waters.[5] In the United States, agriculture is the main source of pollution in rivers and streams, the second main source of pollution in wetlands, and the third main source of pollution in lakes.[6] Pennsylvania is no exception to these trends. Within these data, agriculture is listed second to only resource extraction as a probable source impairing the state's rivers and streams.[7]

Figure 1. Sources of water contaminants in the U.S.

Probable source	Rivers & streams (miles)	Lakes & reservoirs (acres)	Bays & estuaries (miles)
Agriculture	135,855	1,112,048	3,510
Atmospheric deposition (e.g. cars, industrial processes)	85,922	4,215,980	13,931
Industrial	11,388	217,323	3,462
Legacy pollutants	5,771	749,611	21,894
Municipal discharge / sewage	57,237	686,322	5,917
Natural / wildlife	50,702	1,083,193	3,637
Resource extraction	32,975	356,891	180
Urban: runoff / stormwater	49,330	759,483	16,773
Other	9,277	834,283	3,921
Unknown / unspecified source	205,778	4,920,194	20,727

Source: Environmental Protection Agency. (2016). National summary of state information EPA assessed waters of the United States. Available at https://bit.ly/2WFwtzN

Water quality issues flow beyond state borders, impacting regional water supplies and beyond. In 2020, the governor of Maryland instructed the state's attorney general to prepare a litigation strategy against the Commonwealth of Pennsylvania for "repeatedly falling short of necessary pollution reduction goals" outlined in the Chesapeake Clean Water Blueprint, which was established with the U.S Environmental Protection Agency (EPA) in 2010 to set pollution limits for all states in the Bay's watershed. Of the six states and one district involved in the initiative, Pennsylvania was the only one to fail to reach any of its midpoint goals. Again, agriculture was identified as a primary impediment to clean-up efforts: 69% of the nitrogen pollution measured in the Bay is estimated to come from Pennsylvania, and 80% of that material load is estimated to come from the 33,000 farm operations in the Bay watershed within Pennsylvania.

Figure 2. 2018 EPA oversight status for the Chesapeake Clean Water Blueprint

	Agriculture	Urban / suburban	Wastewater
Delaware	Enhanced oversight	Ongoing oversight	Ongoing oversight
District of Columbia	Not applicable	Ongoing oversight	Ongoing oversight
Maryland	Ongoing oversight	Enhanced oversight	Ongoing oversight
New York	Ongoing oversight	Ongoing oversight	Enhanced oversight
Pennsylvania	Backstop action levels	Backstop action levels	Ongoing oversight
Virginia	Ongoing oversight	Ongoing oversight	Ongoing oversight
West Virginia	Ongoing oversight	Ongoing oversight	Ongoing oversight

Ongoing oversight:
EPA does not have significant concerns with a jurisdiction's strategy to implement pollution reduction goals but will continue to monitor progress.

Enhanced oversight:
EPA has identified specific concerns with a jurisdiction's strategy to implement pollution reduction goals and may take additional federal actions, as necessary, to ensure the jurisdiction stays on track.

Backstop action level:
EPA has identified substantial concerns with a jurisdiction's strategy to implement pollution reduction goals and has taken federal action to help the jurisdiction get back on track.

Source: Environmental Protection Agency. (2018). EPA final evaluation of 2016-2017 milestone and midpoint progress and 2018-2019 milestone commitments in the Chesapeake. Available at https://bit.ly/2Cuj3zO

Many of the water quality challenges Pennsylvania is facing within the Chesapeake Bay watershed, in the center of the state, are common to the Delaware River watershed in the east of the state as well. The Delaware River watershed is estimated to deliver the highest nitrogen load per unit area (4.3 tons per square mile per year) and second highest total nitrogen load (50,525 tons per year) of any river basin along the Atlantic.[8] A quarter of this nitrogen is attributed to agriculture.[9]

Still, agriculture does not inherently pollute water—or any other natural resource, for that matter. Conversely, agriculture can serve to protect, and even increase, clean water supplies and significantly improve public and environmental health in the process. The difference between a destructive agricultural system and a restorative one lies largely within how the system is collectively managed by its stewards: the farmers. The Green Revolution in farming realized tremendous production yields through increasingly massive amounts of inputs; it also generated tremendous amounts of waste, much of which wound up in rivers, lakes, aquifers, and oceans.

Photo: Riparian buffers along a stretch of the Susquehanna River in Bradford County, Pennsylvania help protect water from agricultural sediment and nutrient runoff. Credit: Nicholas A. Tonelli

The next revolution in agriculture may be to maintain, or come close to approaching, the admirable yields of the Green Revolution while minimizing external inputs and waste by creating internally regenerative systems, powered by healthy ecosystems. This kind of agriculture is not a dream—there are profitable farms today that are building healthy soil rather than losing it, cycling nutrients rather than leaching them, and capturing water rather than wasting it. The owners and employees of these farms are blending traditional methods for growing and raising food in harmony with natural systems with contemporary advances in agricultural research and technologies.

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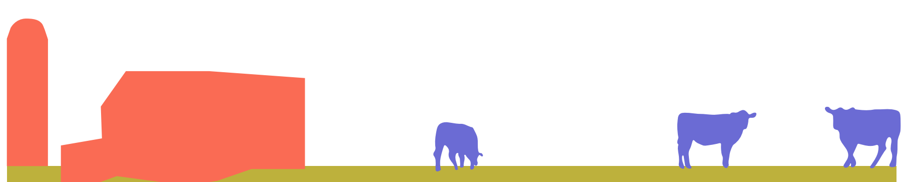
As more farmers implement sustainable and regenerative land management practices, such as the strategies we'll examine in this booklet, the tide can turn: Agriculture can transition from a major source of water pollution to a major force for improving water quality and, in turn, for protecting human and environmental health.



Pennsylvania farmers are responsible for managing over 7 million acres—nearly a full quarter of the state's 29 million acres.[a]

Per dollar spent, improving agricultural practices is one of our best investments toward clean and safe water.

Photo: Riparian buffers designed by Neil Korostoff, Centre County, Pennsylvania. Credit: Google Earth

Opportunities & Solutions

Since the amendment of the Clean Water Act in 1972, the worst *point-source polluters*—that is, pollution that comes from a single location, such as an individual wastewater treatment plant—for the Chesapeake Bay and Delaware River in Pennsylvania have been largely addressed. This left *nonpoint-source pollutants*—pollution that comes from many, less easily identifiable locations—as the primary cause of water impairment. Nonpoint-source pollution includes agricultural runoff and leaching, airborne emissions from industry and automobiles, and urban and suburban stormwater.[10] Agriculture represents a significant challenge toward reducing pollution and protecting clean water, but it also represents a considerable opportunity.

Per dollar spent, improving agricultural practices is one of our best investments toward clean and safe water. The costs associated with reducing nitrogen pollution in water vary depending on the source, but the basic range of dollars spent per pound of nitrogen reduced is only $1.20 to $11 when addressed through agricultural conservation practices. Comparatively, the range of dollars spent per pound of nitrogen reduced by means of improving and expanding wastewater treatment ranges from $8.56 to $79; improving airborne emission controls ranges from $75 to $132; and implementing urban and suburban stormwater retrofit best management practices ranges from $90 to $500.[11]

Figure 3. Cost of reducing nitrogen pollution by source (range of dollars spent per pound of nitrogen reduced)

Agricultural conservation practices	$1.20–$11.00
Improved wastewater treatment	$8.56–$79.00
Improved airborne emissions controls	$75.00–$132.00
Urban/suburban stormwater retrofit best management practices	$90.00–$500.00

In short, farms have the potential to have the greatest impact on water quality per dollar spent. In contrast, the growing issue of urban and suburban stormwater pollution across the region is the most expensive to address. Considering these data, we might conclude that future urban and suburban development needs to manage stormwater much more effectively, while current mitigation dollars might be best spent making farms clean water powerhouses. There are a number of ways farms can realize this role—and, fortunately, many of the most effective strategies are not just good for water, they are also good for business.

Photo: Hairy vetch cover crop. Credit: Hannah Smith-Brubaker, Village Acres Farm

Better Soil, Better Water: Cover Crops

Typically grown between cash crops, when soil would otherwise be fallow, cover crops are primarily grown to protect and improve soil and water. Since they are not usually intended to be harvested and sold, farmers have often viewed cover crops as a questionable investment in time and money. These perceptions have begun to change, however, as more growers are realizing that well-managed cover crops can actually increase overall farm profitability in a relatively short period of time—a recent study published by USDA Sustainable Agriculture and Research Education (SARE) estimated returns on cover crop investment at one to three years.[12] The primary ways farmers realize these increased economic efficiencies is through affiliated improvements in soil and water systems. Cover crops can:

- increase soil health;
- reduce fertilizer applications;
- improve weed control;
- reduce herbicide use; and
- increase water infiltration and retention in soil.

Cover crops specifically benefit water quality by reducing the amount of nutrients, pesticides, and sediment that travels from and through farms fields to waterways and water tables.[13] Studies have shown that cover crops can:

- reduce nutrient and pesticide runoff from farms by greater than 50%;
- reduce pathogen loading from farms into bodies of water by 60%;
- reduce sediment loading from farms into bodies of water by 75%; and
- reduce on-farm soil erosion events by 90%.[14, 15, 16]

Cover crops achieve these results through a variety of methods. They physically intercept rainfall, slowing it down and softening its impact on the earth. They also slow water's flow over the ground's surface, reducing the amount of runoff that happens during storms. Cover crops physically change the soil as well, creating a more porous structure and increasing the amount of living roots, effectively allowing soil to both hold and drain water more efficiently.[17] This is a win-win scenario, enabling soil to simultaneously mitigate potential damage caused by heavy rainfall, as well as hold moisture in times of drought.

John and Aimee Good have had their challenges with water in southeast Pennsylvania. Initially, many of those challenges were a result of having too much water in the low-lying fields they had been leasing. After purchasing a farm in Lehigh County, however, the Goods faced a new challenge: well-drained, shale soils that dry out quickly.

The Goods are using cover crops on their farm as a way to build organic matter in their soil and retain more moisture in their fields. Cover crops are also helping the farm retain nutrients—particularly nitrates—that might otherwise leach from their soil into the water table.[b] This means lower fertilizer costs and fewer irrigation demands for the Goods, and less water pollution overall.

Photo: Lyle Good and farm dog Max play in cover crops including crimson clover, hairy vetch, and wheat.
Credit: Aimee Good, the Good Farm

Photo: Herd at Clover Creek Cheese Cellar, Blair County, Pennsylvania. Credit: Melissa Cipollone, Pasa

Perennial Pastures, Perennial Winners

Perennial pastures can take many of the benefits of cover crops and amplify them multifold, primarily through increased plant species diversity and the persistence of living roots over years, as opposed to months. When livestock graziers manage their herd and land skillfully, pastures can become internally regenerative, sustaining healthy levels of forage and livestock production while building soil fertility without significant external inputs. Compared to tilled land, well-managed, rotationally grazed perennial pastures can:

- decrease soil erosion;
- mitigate flooding;
- require minimal (if any) pesticides and fertilizers;
- increase forage production per acre;
- build soil organic matter;
- sequester carbon; and
- improve animal health.[18]

Perhaps the biggest benefit to water well-managed perennial pastures offer over cropland is decreased soil erosion.[19, 20] Sediment runoff from such pastures, as compared to conventional corn farms and concentrated animal feeding operations (CAFOs), has been estimated to be 87% less.[21, 22] This is significant, considering Pennsylvania had roughly 4.6 million acres of cropland in 2017, much of it intended for livestock consumption. In the same year, pastureland in the state accounted for approximately 700,000 acres.[23]

It is important to note that proper grazing management is key to unlocking the many benefits of perennial pastures, whereas poor management practices, like overgrazing, can erase many of the positive impacts rotational grazing can yield. Further, poor grazing management can cause significant problems, such as increased soil erosion and compaction, as well as decreased forage quantity and quality.[24, 25] Still, even on farms with less-than-optimal pasture management, simple measures—such as restricting livestock access to rivers, creeks, and streams—can lessen some of the worst erosion issues on a farm and prevent manure from directly entering waterways. In a state like Pennsylvania, where CAFOs are present but smaller livestock operations dominate (despite the state being one of the nation's top ten milk producers, the size of an average dairy in Pennsylvania is the second smallest in the country), such easily attainable goals can be a good starting point toward transforming a livestock operation from a water liability into a water asset.

Despite the environmental, nutritional, and animal welfare benefits, raising livestock on pasture remains a niche market—only 5% of the 32 million cattle, 5% of the 121 million hogs, and 0.01% of the 9 billion chickens produced for meat are raised and finished on pasture.[c]

Spring Creek Farm is a multi-generation organic dairy in a quiet corner of Berks County, Pennsylvania. Forrest Stricker, and his son, Greg, manage the land with a herd of rotationally grazed, grass-fed cows. Despite a historic downturn in the dairy industry in recent years, the Strickers have been able to stay in business by diversifying their market and capitalizing on consumer demand for grass-fed dairy.

A nationwide 2018 study compared the fatty acid profile in milk from cows fed a nearly 100% forage-based diet (grassmilk) to milk from cows fed organic and conventional grain and forage diets. The study concluded that conversion to grassmilk systems could help restore a historical balance of fatty acids within dairy products, and potentially reduce the risk of cardiovascular and other metabolic diseases.[d] Research like this points to a conclusion that might feel like common sense to some, but has not yet become commonly accepted: Agricultural practices that improve soil health and water quality also produce healthier food.

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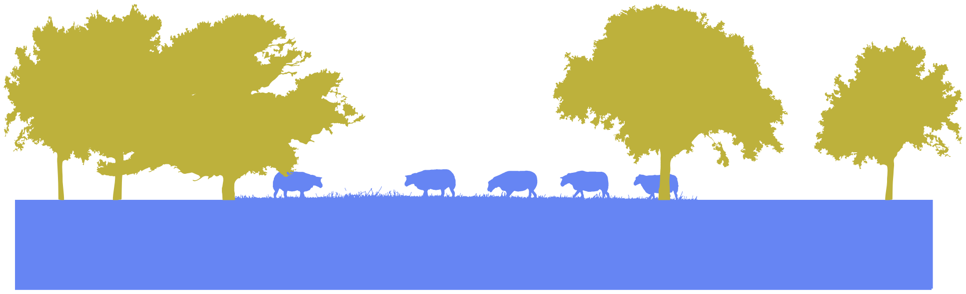
Photo: Herd at Spring Creek Farm, Berks County, Pennsylvania. Credit: Sarah Bay-Nawa, Pasa

Photo: Newly planted forested buffer zone at Willow Run Farm, Berks County, Pennsylvania. Credit: Lamonte Garber, Stroud Water Research Center

Adding Trees, Adding Strength

Both cover crops and perennial pastures help mitigate and even improve water quality in part by increasing the living biomass covering the soil at any given time. Agroforestry practices extend this principle even further, incorporating woody plants into the landscape and thereby increasing the complexity and resilience of the agricultural system. Like building organic matter in soil, woody species on farms can increase the land's capacity to retain and cycle nutrients more efficiently, as well as mitigate both flood and drought.

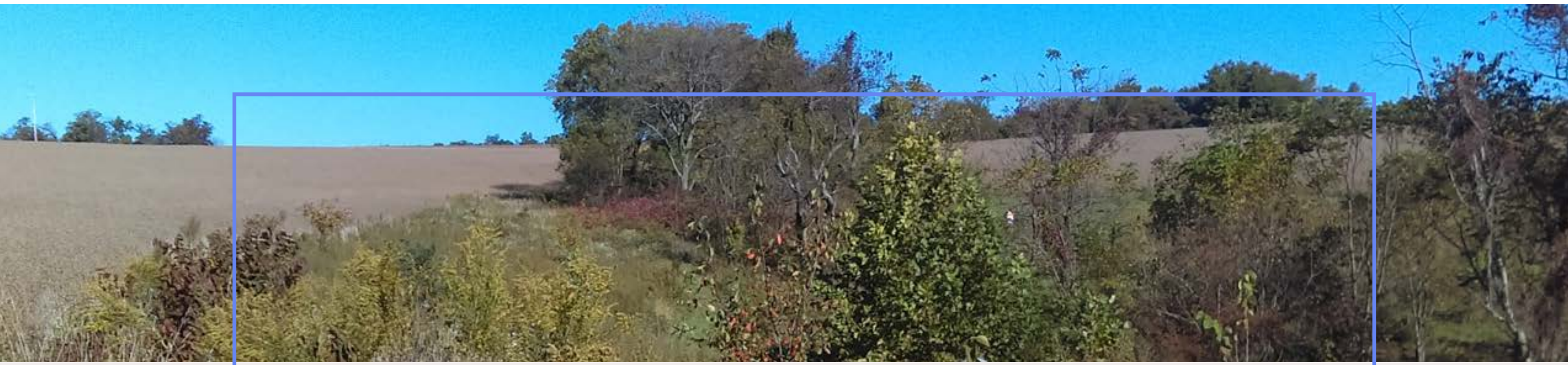


Riparian buffers

The riparian buffer is, today, perhaps the most common example of an agroforestry practice in Pennsylvania. Supported by government initiatives such as the Conservation Resource Enhancement Program (CREP), riparian buffers are forested strips of land located at the margins of farms and along waterways that:

- decrease concentrations of pollutants from entering waterways;
- stabilize water channels, mitigating floods and sediment deposition; and
- increase biodiversity within the riparian and aquatic habitat.

Forested buffers have the incredible capacity to prevent up to 85% of all common agricultural pollutants from entering ground and surface waters.[26] In order to achieve such efficacy, though, buffers need to be well-placed and well-managed. An effective buffer is approximately 30 feet wide, at minimum, on either side of a stream, though a width of at least 100 feet is closer to ideal.[27] The best buffers are also complemented by other agricultural conservation strategies upslope, like cover crops and well-managed pastures, that work to reduce excessive nutrient applications on farms from the start.

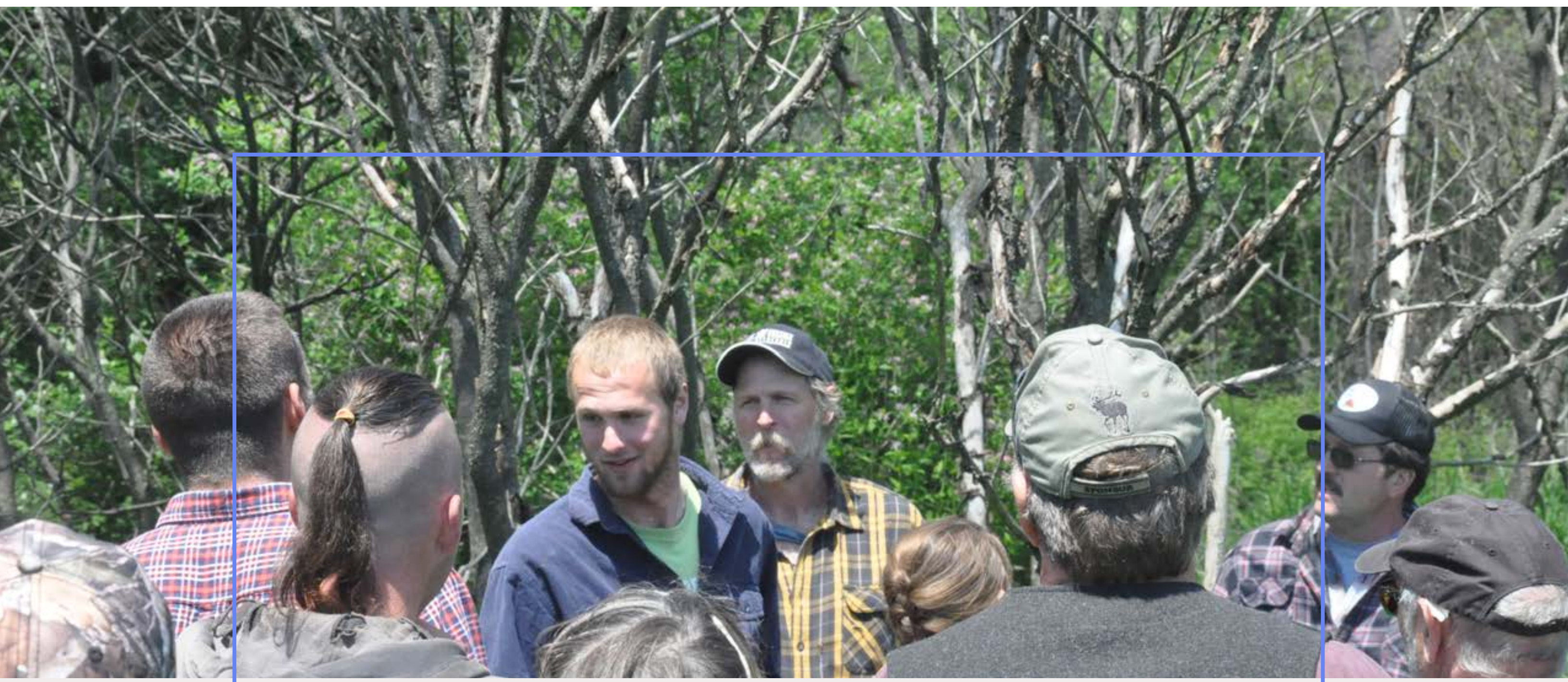


Anne and Don English, a landscape architect and an economist with the USDA Forest Service, respectively, have been experimenting with riparian buffers on their property in York County, Pennsylvania for years. Cultivated along the banks of a small stream, Anne and Don's buffer protects the headwater creek from the possible incursion of pollutants from bordering row crop fields. Water flowing overland, carrying sediments and phosphorus, for instance, is intercepted by the perennial grasses and trees of their buffer, while water flowing beneath the surface is absorbed by deep-rooted plants before nutrients, such as nitrates, can enter waterways.[e] Anne and Don incorporated a variety of food and fiber species into their riparian buffer that may be harvested, as well, expanding the multi-functional nature of their system.

Photo: Riparian buffer at Happy Hollow Farm, York County, Pennsylvania. Credit: Aaron de Long, Pasa

Silvopasture

Silvopasture—establishing trees on perennial pastures, or converting existing forest into a forested grazing system—is another agroforestry practice that is on the rise in Pennsylvania and beyond, as livestock managers seek to provide shade for their herds, diversify their income, and introduce novel forage sources. Beyond conferring management advantages to the skilled grazier, establishing trees on pasture and farmland can lead to improvements in soil, water, and air quality, as well as help modify local and global climate extremes.[28]



In Bradford County, Pennsylvania, young dairy grazier Joseph Moyer has been experimenting with silvopasture practices on his family farm. Adding trees to the Moyers' pasture system, mimicking a savannah landscape, should aid in nitrate scavenging and increase retention of phosphorus in the soil, as opposed to treeless pastures.[f] Trees can also provide protection from water and wind erosion, in addition to the protection provided by the perennial herbaceous species that comprise the Moyers' pastures.[g] For Joseph's dairy herd, the trees will also provide shade for the cows, supporting their health and wellbeing, and possibly ancillary income in future years through timber, forage, and nut harvests.

Photo: Joseph Moyer discusses silvopasture strategies at a Pasa workshop with other local graziers. Credit: Aaron de Long, Pasa

Photo: Swales at Lundale Farm Preserve, Chester County, Pennsylvania. Credit: Aaron de Long, Pasa

Rethinking Design, With Water in Mind

Beyond management principles of crop fields and pastures, the overarching design or layout of a farm property can also have an impact on water quality. This might include how row crops are oriented, where pastures are fenced, and, significantly, how animals and people are moving across the landscape.

In order to manage water most effectively and efficiently, a farm manager must first observe how water moves across their land. By recognizing primary flow pathways, the manager can then design field and building layouts that will slow and spread water's movement across the land, ideally increasing the farm's water storage capacity while reducing or even eliminating flooding issues. There are a number of design principles farmers can put into practice that are focused on optimizing the flow and conservation of water in this way, including Keyline design and other land contour-based management systems.

Vegetable farmers Jasper Williams and Eliza Killo at Sankanac CSA in Chester County, Pennsylvania have taken a landscape-design approach to mitigate water issues while increasing productivity on their farm. By installing a series of living swales and berms on a slight contour across their main production field, and contouring the cultivated terrain at a 1% grade, Jasper and Eliza have largely alleviated the water pooling issues that were robbing the farm of some of its most productive ground in wet years, as well as the flooding events that would occasionally wash topsoil into the nearby creek. The berms and swales have since been seeded to perennial species, with an abundance of clover in the mix, building soil and fertility. Jasper and Eliza have seen significant increases in pollinators as a result of the perennial berms, and have had a much easier time cultivating their crop acres, year-round.

"Seeing the effects this kind of landscape management can have has changed the way we farm in many ways," Jasper explains. "We think about water and drainage all the time, and managing water skillfully for greater productivity. For instance, we still till, but we've changed our primary tillage tool to a spader, over a moldboard plow or rototiller. Even that has made a difference in allowing better drainage in the soil, both through fewer tractor passes and through the implement's basic design. Every little bit matters. Every drop counts."

Photo: Jasper Williams at Sankanac CSA in Chester County, Pennsylvania discusses the farm's berm-swale field design. Credit: Aaron de Long, Pasa

Photo: In addition to a series of berms and swales, Sankanac CSA in Chester County, Pennsylvania also graded their main production field at 1% to facilitate water movement and prevent flooding. Credit: Aaron de Long, Pasa

Flooding the Neighborhood

While agriculture is a major source of water pollution, it is not the only culprit. Urban and suburban water pollution, typically in the form of stormwater runoff, is a growing issue across the U.S. In 2017, an estimated 10 trillion gallons of stormwater runoff entered waterways from developed areas "containing everything from raw sewage to toxins to trash," leading the American Society of Civil Engineers to give the country a D+ grade for its stormwater and sewage systems.[29]

More frequent heavy rainfalls that overload stormwater systems is part of this equation, but an increase in impervious (paved) surfaces is another important aspect.[30] Combining and analyzing 25 years of runoff data, researchers found that a 1% increase in impervious basin cover causes an average 3.3% increase in annual flood magnitude.[31] Simply put: Development exacerbates flooding. One inch of rain falling on an acre of pavement creates approximately 27,000 gallons of runoff. In contrast, one inch of soil organic matter on one acre of farmland has the capacity to absorb 20,000 gallons of water.[32] Development might be necessary, but sustainable development might necessitate the inclusion of farms, not only for providing healthy food but for protecting water as well.

Fred and Paula de Long live in a leafy suburb of Philadelphia. When their children were young in the 1980s, the creek that flowed through their property was a neighborhood asset. The children played in it regularly, it was an attractive landscape feature, and flooding was rare. Approximately forty years later, however, flooding is regular, and the creek is a source of local debate and controversy.

Landowners built stone walls along the creek decades ago, primarily for aesthetics; now, the walls are a bulwark against increasingly frequent and heavy storms, even while they exacerbate flooding issues in neighborhoods downstream. Fred and Paula want to help their downstream neighbors, but they fear that if they take down their creek wall, and their neighbors don't follow suit, the creek will have an outsized impact on their property. There's too much personal and financial risk for them to take action on their own.

Situations like Fred and Paula's are not uncommon in the Commonwealth, but they are difficult to resolve. There are many stakeholders in developed communities, and coming to consensus on issues around a shared watershed can take significant time and money. By contrast, farmers typically own or manage relatively large areas of land, and the potential for a single person to create substantive, positive impact on a watershed through skilled management is much more straightforward.

Photo: Fred de Long stands next to the walled-in stream on his property. The orange flags to the left represent where restoration planners believe the creek could shift if the wall is removed. Credit: Aaron de Long, Pasa

Comparing land use and pollution data from the USDA and EPA, agriculture and urban and suburban development show a similar water impairment impact per unit area on rivers and streams within Pennsylvania. As cited earlier, however, a key difference between mitigating water pollution from agricultural sources versus development sources is cost. The basic range of dollars spent per pound nitrogen reduced is anywhere from nine to 400 times more expensive to retrofit urban and suburban areas for best management practices, as compared to implementing conservation practices on agricultural lands. Shifting the laneways on a farm, or introducing cover crop regimes, riparian buffers, or improved grazing practices, is much simpler than relocating houses, roads, and sewer systems.

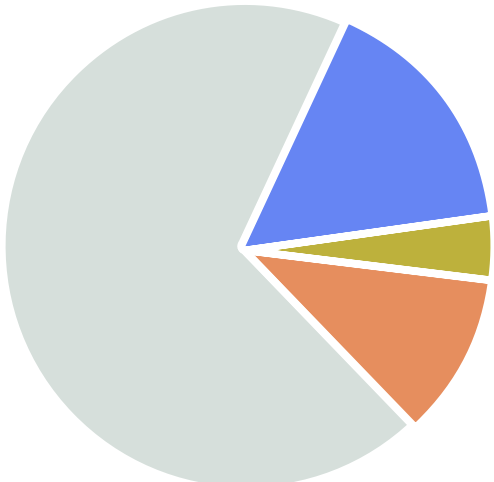
Figure 4. Miles of rivers & streams impacted per unit area

Cropland plus grassland pasture & range	Urban areas
.9 miles impacted per 1,000 acres	1 mile impacted per 1,000 acres

Source: Environmental Protection Agency (EPA). (2016). National summary of state information EPA assessed waters of the United States. Available at https://bit.ly/2ZpBezd

In many ways, farms represent low-hanging fruit for water quality improvements compared to developed areas, which is especially relevant when we consider the significant pressures that have been shifting tens of millions of acres of farmland into development across the nation over the last several decades. It’s estimated that Pennsylvania alone lost nearly 350,000 acres of farmland to development in the 15 years spanning from 2001 to 2016—the seventh highest number in the nation.[33]

Figure 5. Major uses of land (subset), Pennsylvania
Area given in 1,000 acre units, followed by percentage of total area



Source: Bigelow, D., & Borchers, A. (2012). Major uses of land in the United States, 2012. United States Department of Agriculture Economic Research Service. Available at https://bit.ly/3iXaL3L

Valuing Farms, Valuing Water

Best management practices like those described in this booklet can increase farm productivity and enhance water quality and quantity. Yet, there are barriers preventing farmers from adopting these practices, including lack of knowledge, lack of capital, and lack of institutional support. These practices often involve new kinds of equipment and require new kinds of research to understand optimal management strategies. Government agencies like the Natural Resources Conservation Service (NRCS) have been valuable partners for many farmers in regard to cost-sharing conservation projects, but often the scope of what the agency can ultimately provide is limited. Other programs like the Conservation Stewardship Program (CSP) and the Environmental Quality Incentives Program (EQIP) can also help fill some of these gaps in knowledge and resources, but such programs and their target deliverables need to move from the fringe to the center of farm policies, both on the state and federal level, to have an appreciable impact on reducing agricultural water pollution.

Traditionally, federal farm policies have provided little incentive for farmers to adopt ecologically-driven management practices that can address myriad issues, from water to soil and air.[34] The federal crop insurance program, for instance, "effectively discourages farmers from planting more than a couple of crops (wheat, cotton, corn, and soy) and gives them an incentive to plant on risky land."[35] There have even been instances where crop insurance contracts were negated when cover crops were used, due to uncertainty regarding cash crop yields.[36]

Fortunately, there are signs that some of these policies are changing. In 2017, Iowa's state agricultural department launched a three-year demonstration program providing a 5% discount on crop insurance to farmers who plant cover crops, and Maryland's Department of Agriculture now pays farmers approximately $45 per acre for growing cover crops, including bonuses for early planting. In 2020, Ohio also announced plans to provide technical support and pay farmers to implement practices that specifically reduce phosphorus runoff, a major issue for Lake Erie. Rates average from $2 to $60 per acre, depending on the practice.[37] Government incentives like these can be critical tools to both effect real change in farming practices and invest in water quality at the farm level, rather than downstream, where mitigation costs become increasingly expensive. These incentives recognize that farmers who invest in acquiring the knowledge, tools, and equipment to effectively implement conservation practices are providing an essential, cost-effective public service.

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After working as a librarian, Deanne Boyer returned to her family farm in 2016 to help her father transition her family's traditional corn and soy farm into a pastured beef cattle farm. A partnership between Deanne's family, their local Conservation District, the Natural Resources Conservation Service, and Stroud Water Research Center, helped the family find the funding to expand the farm's perennial pastures from near 10 to over 40 acres, create improved laneways and stream crossings, and establish a 100-foot-wide riparian buffer. The buffer, in particular, performed admirably in the flood year of 2018, protecting their farm and other farms downstream from significant water damage.

While there are some things Deanne notes she might have done differently, she'd never go back to the way the farm was. Willow Run Farm has become an example of how creative partnerships between agricultural landowners and local, state, and national organizations can help Pennsylvania transform farms from water polluters to water protectors.

Photo: Grazing paddocks and the cow-calf beef operation at Willow Run Farm in Berks County, Pennsylvania. Credit: Lamonte Garber, Stroud Water Research Center

Water is the thread that most tangibly connects us all, and the costs of poor water management are borne by everyone in a society. Agriculture is responsible for some of the most serious water quality issues we are facing in Pennsylvania and globally, but farms, and the farmers who steward them, also represent perhaps our greatest opportunity for realizing a cleaner, safer, and more sustainable water supply. Instrumental to this transformation will be support for farmers from multiple strata of society—including policymakers, researchers, and consumers—as we collectively realize, quantify, and incentivize farms that produce benefits beyond single cash crops. Ultimately, farmers that grow not only food, but regenerative farm ecosystems, as well, need to be recognized for the innumerable public health and environmental benefits they are providing to everyone who lives both upstream and down, under a common sky.

Photo: Zoe Schaeffer planting flowers at Pasture Song Farm, Pottstown, Pennsylvania. Credit: Zoe Schaeffer

References

1. Mateo-Sagasta, J., Zadeh, S., & Turral, H. (2017). Water pollution from agriculture: A global review. *Food and Agriculture Organization of the United Nations.*

2. Alexander, RB, Smith, R., Schwartz, . . . G., Brakebill, J. (2008). Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. *Environmental Science Technology, 42, 3. 822-30.*

3. Center for Disease Control and Prevention. (2020). Atrazine and your health. *Community Water.* Available at https://ephtracking.cdc.gov

4. Mateo-Sagasta, J., Zadeh, S., & Turral, H. (2017). Water pollution from agriculture: A global review. *Food and Agriculture Organization of the United Nations.*

5. Mateo-Sagasta, J., Zadeh, S., & Turral, H. (2017). Water pollution from agriculture: A global review. *Food and Agriculture Organization of the United Nations.*

6. Environmental Protection Agency. (2016). National summary of state information EPA assessed waters of the United States. Available at https://ofmpub.epa.gov/waters10/attains_nation_cy.control#total_assessed_waters

7. Environmental Protection Agency. (2016). National summary of state information EPA assessed waters of the United States. Available at https://ofmpub.epa.gov/waters10/attains_nation_cy.control#total_assessed_waters

8. Kauffman, G J. (2018). The cost of clean water in the Delaware River Basin. *Water, 10,* 2.

9. Environment America Research and Policy Center. (2016). Threats to clean water in the Delaware River Basin. Available at https://environmentamerica.org/sites/environment/files/cpn/Delaware_Watershed_Factsheets/Summary_of_Threats_in_the_Delaware_River_Basin-Environment_America.pdf

10. Ehrhart, M., & Jackson, J. (2018). Agriculture policy and practice in the Delaware and Chesapeake watersheds. *Water Resources Impact, 20*(5), 22-23.

11. Kauffman, G J. (2018). The cost of clean water in the Delaware River Basin. *Water, 10,* 2.

12. Meyers, R., Weber, A., & Tellatin, S. (2019). Cover crop economics. *USDA-SARE Technical Bulletin.* Available at: https://www.sare.org/Learning-Center/Bulletins/Cover-Crop-Economics

13. Hoorman, J.J. (2009). Using cover crops to improve soil and water quality. Ohio State University. Available at https://ohioline.osu.edu/factsheet/anr-57

14. Sweeney, B. W., & Blaine, J. G. (2016). River conservation, restoration, and preservation: Rewarding private behavior to enhance the commons. *Freshwater Science 35* (3), 755-763.

15. Hoorman, J. J. (2009). Using cover crops to improve soil and water quality. Ohio State University. Available at https://ohioline.osu.edu/factsheet/anr-57

16. Dabney, S. M., Delgado, & J. A., Reeves, D. W. (2001). Using winter cover crops to improve soil and water quality. *Community of Soil Science Plant Analysis, 32*(7&8), 1221-1250.

17. Basche, A. (2017). Turning soils into sponges. Union of Concerned Scientists. Available at https://www.ucsusa.org/sites/default/files/attach/2017/08/turning-soils-into-sponges-full-report-august-2017.pdf

18. Undersander, D., Albert, B., Cosgrove, D., . . . Peterson, P. (2002). Pastures for profit: A guide to rotational grazing. University of Wisconsin-Extension. Available at https://fyi.extension.wisc.edu/wbic/files/2010/11/Pastures-to-profit.pdf

19. Undersander, D., Albert, B., Cosgrove, D., . . . Peterson, P. (2002). Pastures for profit: A guide to rotational grazing. University of Wisconsin-Extension. Available at https://fyi.extension.wisc.edu/wbic/files/2010/11/Pastures-to-profit.pdf

20. Hubbard, R.K., Newton, G. L., & Hill, G. M. (2004). Water quality and the grazing animal. *Publications from USDA ARS / UNL Faculty.* 274.

21. Chesapeake Bay Foundation. (2020). Best management practices. Available at https://www.cbf.org/issues/agriculture/best-management-practices.html

22. Undersander, D., Albert, B., Cosgrove, D., . . . Peterson, P. (2002). Pastures for profit: A guide to rotational grazing. University of Wisconsin-Extension. Available at https://fyi.extension.wisc.edu/wbic/files/2010/11/Pastures-to-profit.pdf

23. National Agricultural Statistics Service. (2018). U.S. Census of Agriculture 2017.

24. Walton, P.D., Martinez, R., & Bailey, A. W. (1981). A comparison of continuous and rotational grazing. *Journal of Range Management, 34,* 1.

25. Teague, W. R., & S. L. Dowhower. (2003). Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks. *Journal of Arid Environments, 53*(2), 211-229.

26. Zhang, X. (2009). A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution. *Journal of Environmental Quality, 39*(1), 76-84.

27. Wenger, S. (1999). A review of the scientific literature on riparian buffer width, extent and vegetation. University of Georgia. Available at https://pdfs.semanticscholar.org/866a/e8d8a9fc075bf9f057af72b6ea2131ea54a0.pdf

28. Smith, Jo, Pearce, B. D., & Wolfe, M. S. (2013). Reconciling productivity with protection of the environment: Is temperate agroforestry the answer? *Renewable Agriculture and Food Systems, 28*(1), 80-92.

29. Denchak, M. 2018. Water pollution: Everything you need to know. Natural Resource Defense Council. Available at https://www.nrdc.org

30. Wright, D. B., Bosma, C. D., & Lopez-Cantu, T. (2019). U.S. hydrologic design standards insufficient due to large increases in frequency of rainfall extremes. *Geophysical Research Letters, 46*(14), 8144-8153.

31. Blum, A. G., Ferraro, P. J., Archfield, S. A., & Ryberg, K. R. (2020). Causal effect of impervious cover on annual flood magnitude for the United States. *Geophysical Research Letters, 47,* 5.

32. Bryant, L. (2015). Organic matter can improve your soil's water holding capacity. Natural Resource Defense Council. Available at https://www.nrdc.org/experts/lara-bryant/organic-matter-can-improve-your-soils-water-holding-capacity.

33. Freedgood, J., Hunter, M., . . . Sorensen, A. (2020). Farms under threat: The state of the states. American Farmland Trust. Available at https://farmland.org/project/farms-under-threat/

34. Basche, A. (2017). Turning soils into sponges. Union of Concerned Scientists. Available at https://www.ucsusa.org/sites/default/files/attach/2017/08/turning-soils-into-sponges-full-report-august-2017.pdf

35. Webber, T., & Funk, J. (2019). Flooded farmers face growing dilemma in warming world. Associated Press. Available at https://apnews.com

36. National Wildlife Federation. (2012). Roadmap to increased cover crop adoption. Available at https://www.nwf.org/~/media/PDFs/Global-Warming/Policy-Solutions/Cover_Crops_Roadmap%20Report_12-12-12.ashx

37. Nicole R. (2020). The Lake Erie Bill of Rights is dead. A voluntary effort will pay farmers to reduce runoff instead. Civil Eats. Available at https://civileats.com/2020/06/22/the-lake-erie-bill-of-rights-is-dead-a-voluntary-effort-will-pay-farmers-to-reduce-runoff-instead/

a. Robertson, G. P., Gross, K. L., . . . Swinton, S. M. (2014). Farming for ecosystem services: An ecological approach to production agriculture. *BioScience, 64,* 5, 404-415.

b. Egan, F., & Miller, B. (2020) Scaling up pastured livestock production: Benchmarks for getting the most out of feed & land. Pasa Sustainable Agriculture.

c. Średnicka-Tober, D., Baranski, M. . . . Leifert, C. (2016). Higher PUFA and n-3 PUFA, conjugated linoleic acid, α-tocopherol and iron, but lower iodine and selenium concentrations in organic milk: A systematic literature review and meta- and redundancy analyses. *British Journal of Nutrition, 11e*(6), 1043-1060.

d. Mateo-Sagasta, J., Zadeh, S., & Turral, H. (2017). Water pollution from agriculture: A global review. *Food and Agriculture Organization of the United Nations.*

e. Smith, Jo, Pearce, B. D., & Wolfe, M. S. (2013). Reconciling productivity with protection of the environment: Is temperate agroforestry the answer? *Renewable Agriculture and Food Systems, 28*(1), 80-92.

f. Nair, V., Haile, S. G., . . . Ramachandran Nair, P. K. (2007). Environmental quality improvement of agricultural lands through silvopasture in southeastern United States. *Scientia Agricola, 64,* 5.

g. Bennett, S. (2020). Silvopasture: The benefits of integrating trees with livestock. National Resource Conservation Service (NRCS). Available at https://nrcs.usda.gov

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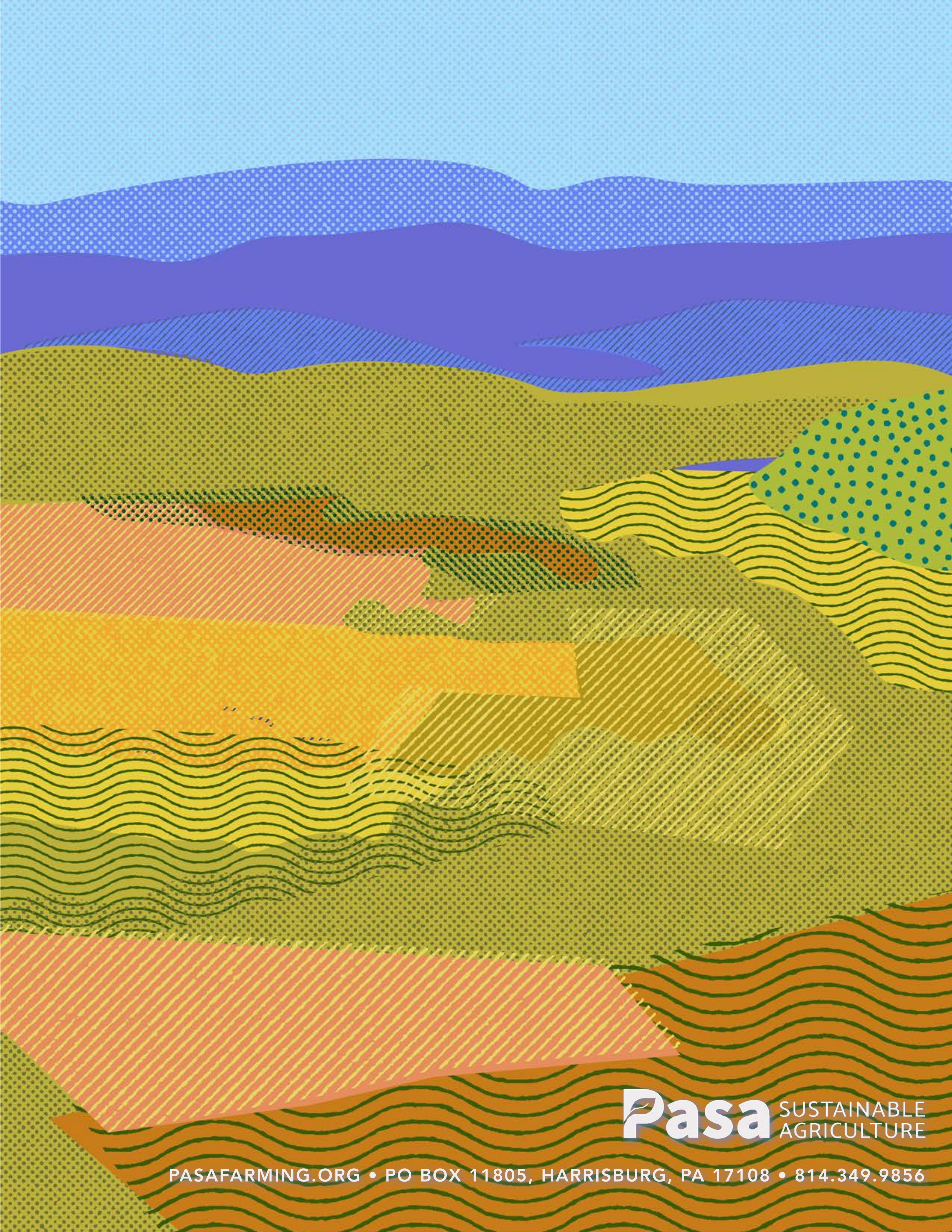
Photo: Grazing perennial pastures at Bobolink Dairy, Hunterdon County, New Jersey. Credit: Aaron de Long, Pasa



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