Animal Grazing Impacts on WATER QUALITY at Solar Electric Generation Sites

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Background

Solar electric power generation is becoming a sought-after solution to the energy needs of individual households, communities, and regions across the United States and around the world. Though the technology has existed for decades, recent improvements in solar panels have made them both more efficient and more cost-effective. These improvements have transformed solar power into an attractive alternative to fossil fuel energy. Additionally, solar power meets the needs of a growing demand for electricity while addressing the challenges of climate change. It's a win-win for communities and the planet. While solar installation sites are quiet and devoid of noisy turbines and unsightly smoke stacks, regular maintenance is required. This includes maintenance of the electrical systems, panels, and vegetation surrounding the panels. One method for managing vegetation at solar sites is to use grazing animals, typically sheep, whose grazing patterns complement the types of vegetation often present in solar setups. To understand how grazing animals at a site might impact adjacent water resources, this paper reviews and summarizes research on grazing practices and water quality. The author also examined the proposed Hecate solar project site in Coxsackie, NY, to assess potential water quality issues associated with the use of grazing animals to manage vegetation at the solar array.

An Increasing Reliance on Solar Power for Electricity Generation

Across the country and around the globe, communities are turning to solar power to meet their energy needs while reducing dependence on fossil fuels. In 2019, New York State set aggressive goals under the Climate Leadership and Community Protection Act. This legislation aims to achieve 70% of New York's electricity generation through renewable resources by 2030. Even more ambitious is the state's goal to achieve 100% zero-emission electricity by 2040. As the New York Climate Action Council states, "Achieving the ambitious goals of this law will mean transforming the way we generate and use electricity."[1] A major part of this plan is the goal of generating 6000 megawatts (MW) of electricity from solar power sites.[2] This will require hundreds of solar power sites across the state, such as the Hecate Energy site proposed for development in Coxsackie. This project aims to develop 40 MW of energy on less than 400 acres.

Siting and Maintenance of Solar Power Sites

Utility-scale solar power generation facilities require land that is open, relatively level, free of obstructions and accessible by personnel for construction and maintenance. In the Northeast, land with these characteristics is relatively rare and is often already dedicated to agricultural production. To address the competing interests of land for agriculture and energy generation, some sites have adopted co-location, the simultaneous use of land for both of these enterprises. According to a 2013 report from the National Renewable Energy Laboratory:

> Vegetation-centric approaches to co-location of solar energy and vegetation are characterized by actions that serve to maximize biomass production activities and minimize changes to existing vegetation management activities, while also incorporating solar energy production activities. Vegetation-centric approaches may be well suited to areas that are land constrained (e.g., the northeast United States) or that are already developed agricultural areas. The basic premise is that the vegetation productivity of the land being utilized is not sacrificed for the sake of solar generation.[3]

1 New York State Climate Action Council. (2020) "Climate leadership and community protection fact sheet." NY, https://climate.ny.gov/-/media/CLCPA/Files/CLCPA-Fact-Sheet.pdf

2 Ibid. Version 1. p. 1. New York State Climate Action Council. (2020) https://climate.ny.gov/

3 Macknick, J., Beatty, B., & Hill, G. (2013) Overview of opportunities for co-location of solar energy technologies and vegetation. Technical Report NREL/TP-6A20-60240 National Renewable Energy Laboratory

Co-location lessens the competition between solar and agricultural enterprises by generating a dual use scenario. While this review focuses on the Northeastern United States, the findings may be applicable to other regions.

Maintaining New Solar Power Sites

Solar electric power stations require regular upkeep and maintenance. Aside from the electrical and structural maintenance of the sites, significant effort is put into maintaining vegetation that grows between and around the solar panels. If left unchecked, vegetation shades the solar panels, reducing energy generation. According to analyses by the Department of Energy's InSPIRE project, "Vegetation management can often account for 3–8% of yearly O&M [Operations and Maintenance] spending. Typical O&M activities to manage vegetation involve mowing, application of herbicide, and hand pulling weeds."[4] A new and promising trend is the use of small ruminants, primarily sheep, to maintain the vegetation at ground mounted solar sites. This process involves moving the animals through the site to consume vegetation and eliminate or reduce the need for mowers or chemical sprays. As Penn State Extension educator David Hartman notes, "Sheep are very well-suited to maintain solar arrays and have proven to be a cost-effective option for solar power companies."[5] University of Massachusetts Amherst researchers have found that "Livestock can effectively manage vegetation underneath solar arrays, and can provide multiple benefits to solar providers and grazing entities. Sheep grazing can reduce mowing and herbicide use."[6] Grazing sheep not only provide a cost-effective and ecological way to manage vegetation at solar sites, but also benefit shepherds utilizing solar sites as pasture land.

The Benefits of Grazing Sheep at Solar Sites

In 2018, the David R. Atkinson Center for a Sustainable Future at Cornell University funded research to compare traditional land management techniques and sheep grazing to control vegetation at solar sites. Traditional practices involve mowing with tractors and use of string trimmers to manage the vegetation. On average, the researchers found, "sites in warm, humid, summer continental climate zones are mowed two or three times per year and undergo one string trimming to remove the vegetation underneath the panels."[7] This approach is contrasted with the use of sheep that manage vegetative growth through the grazing process. After field trials in 2018 at Cornell's Musgrave Research Farm in Aurora, NY, researchers observed that sheep, shepherds, and the solar utility all benefited:

> The sheep left the site healthy at the end of the season, with good body condition and low parasite load. The goals for both the solar company and the shepherd farmer were met in this grazing trial. Vegetation never shaded the panels, and the farmer was compensated at a profit for extra work at a remote location.[8]

In addition to the field trials, researchers surveyed sheep farmers grazing additional solar sites from North Carolina to Ohio and across the Northeastern United States. The experiences of the sheep farmers and the Cornell trial data demonstrated positive outcomes for both the farmers and the operators managing the solar sites. In conclusion, the study determined that:

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4 Macknick, D. (2020) Innovative site preparation and impact reductions on the environment. *Low-Impact Solar Development Strategies Guidebook*. National Renewable Energy Laboratory, U.S. Department of Energy

5 Hartman, D. (2020) *Sheep grazing to maintain solar energy sites in Pennsylvania*. Penn State Extension. https://extension.psu.edu/sheep-grazing-to-maintain-solar-energy-sites-in-pennsylvania

6 Macknick, D. (2020) Innovative site preparation and impact reductions on the environment. *Low-Impact Solar Development Strategies Guidebook*. National Renewable Energy Laboratory, U.S. Department of Energy

7 Kochendoerfer, N., A. Hain, and M. Thonney. 2019. The agricultural, economic and environmental potential of co-locating utility scale solar with grazing sheep. Atkinson Center for a Sustainable Future, Cornell University, Ithaca, NY.

8 Ibid. p 3.

> Grazing sheep on solar sites is a cost-effective method to control on-site vegetation and prevent panel shading. It was less labor-intensive than traditional landscaping services and, thus, less expensive. The grazing trial at the Musgrave solar site was a full success for the site owners and operators, as well as the sheep farmer.[9]

This research shows that grazing sheep at solar sites can benefit the farmer and the solar site operator while promoting flock health; this study did not, however, collect data on how co-location might affect nearby water quality. Other studies have documented how livestock grazing near water bodies and wetlands can affect surface water quality.

Water Quality Impacts of Grazing Animals

Grazing animals on solar electric generation sites is a cost-effective and ecologically beneficial method of vegetation management. However, there are related aspects of grazing operations that must also be considered. According to *Time* magazine, the U.S. lost more than 100,000 farms between 2001 and 2018.[10] The immense financial pressures on agriculture make time scarce for the average farmer. Due to these pressures on farmers, "a large portion of pastures in the eastern U.S. are relatively unmanaged."[11] Many ruminant herds roam freely on large tracts of land, a practice known as "continuous grazing." Such animals are seldom, if ever, moved to a new or different pasture, nor is their number increased or decreased based on weekly or monthly forage availability, but on a set stocking rate for the whole season. In some areas where cropland is extremely high-value, livestock grazing is limited to the field edges and areas unsuitable for cropping–often the steeply sloped, timbered areas around streams. In continuous grazing, animals often have unrestricted access to surface water–including streams and ponds–and disturb nearby soil in ways that promote runoff into watersheds. While low maintenance, low cost, and low labor for the farmer, this "poorly managed grazing of beef cattle in riparian areas may contribute to sediment and nutrient loading of... surface waters."[12]

The prevalence of this style of unmanaged grazing, with unrestricted access to natural water resources, has led to an impression that grazing animals in any proximity to a water body will result in negative water quality impacts. As Leslie M. Roche, an expert in rangeland ecology and management at the University of California, Davis notes, "There is substantial concern that microbial and nutrient pollution by cattle... degrades water quality, threatening human and ecological health."[13] All ruminants, however–including cattle, sheep, goats, llamas, and others–require proactive management to achieve healthy pastures and healthy watersheds. If they are allowed to roam freely, they "may also reduce water quality by the deposition of nutrients and pathogens in their manure within or near streams."[14]

Allowing grazing animals to roam freely in water bodies also can affect siltation (sediment buildup) and eutrophication, which results in excess nutrients turning into harmful algae blooms that kill healthy aquatic organisms.

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9 Ibid. p 6.

10 Semuels, A. (2019, November). "'They're trying to wipe us off the map.' Small American farmers are nearing extinction." *Time*.

11 Franzluebbers, A., Owens, L., Sigua, G., Cambardella, C., & Haney, R. (2012) Soil organic carbon under pasture management. In *Managing Agricultural Greenhouse Gases* (pp.093-110). DOI:10.1016/B978-0-12-386897-8.00007-3.

12 Haan, M.M., Russell, J.R., Morrical, .G., & Strohbehn, D.R. (2007) "Effect of grazing management on cattle distribution patterns in relation to pasture streams." Animal Industry Report: AS 653, ASL R2205. p. 1.

13 Roche, L.M., Kromschroeder, L., Atwill, E.R., Dahlgren, R.A., & Tate, K.W. (2013) Water quality conditions associated with cattle grazing and recreation on National Forest lands. *PLoS ONE* 8(6): e68127. https://doi.org/10.1371/journal.pone.0068127

14 Russell, J., Haan, M., & Bear, D. (2008, February 23) Grazing management of beef cows to limit non-point source pollution of streams in Midwestern pastures. Cornbelt Cow/Calf Conference, Ottumwa, IA.

Through dedicated research, graziers, conservation groups, and water quality advocates have discovered some simple practices to address these concerns. These practices include "exclusion of livestock grazing (in water bodies), alternative grazing schemes such as rotational stocking, management of riparian areas as special use paddocks, stabilized access sites, and off-stream salt and mineral supplementation and/or water sites."[15] By employing these practices, farmers have demonstrated significant improvements in water quality. While "a variety of management practices have been proposed to alter cattle distribution patterns and reduce the associated damage to streams and riparian areas,"[16] these practices can be grouped into five main categories for improving water quality:

1. Restrict access: erect a physical barrier between the animals and protected water resources like lakes, ponds, seeps, springs, streams, and wetlands.
2. Protect riparian and coastal buffer zones: delineate and separately manage the zones directly adjacent to—and thus the most likely to influence—water resources.
3. Promote vegetative quality of the pastures: manage the pasture to maintain desired levels of plant density and residual plant height.
4. Maintain and promote good soil health: improved soil benefits vegetation production and diversity, enhances buffer zone benefits, and promotes hydrological function throughout a site.
5. Actively manage grazing: the key factor in promoting the previous elements that protect water quality.

By examining each of these dimensions of water quality protection, we can outline the practices and management techniques needed to assure water quality in areas adjoining lands under active farm management.

Eliminate Direct Access to Water Bodies

It has long been known that "pasture conditions that promote frequent gatherings of cattle near streams and ponds may increase sediment, nutrient and pathogen loading of these water sources from manure deposition, as well as bank erosion."[17] Allowing grazing animals direct access to a water source creates negative outcomes for water quality. Farmers whose animals have unrestricted access to streams or ponds avoid the expense of installing wells, waterlines, feed troughs, and the like, and increase the simplicity of providing water for their animals. Though less expensive, this approach certainly does not promote water quality, nor does it promote healthy streams: "Cattle grazing in riparian areas can result in two types of erosion within the stream channel. As cattle enter and leave a stream, their hooves on the soil surface can cause mechanical breakdown of the banks. Cattle grazing also removes vegetation from the soil surface, leading to bank scour on vertical sides of the stream."[18] Both physical disturbance of stream banks and loss of vegetative cover lead to erosion, turbidity, and other water quality issues. Furthermore, unrestricted animals can deposit urine and fecal matter directly into the water, introducing pathogenic contamination and nutrient loading. It is abundantly clear that keeping animals out of streams is critically important to protecting water quality. Research has shown that "management practices that utilize fencing provide the most direct method of excluding or limiting cattle access to pasture streams."[19]

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15 Ibid. p. 1.

16 Ibid. p. 1.

17 Russell, J.R. & Shouse, S.C. (2008) "A guide to managing pasture water: Stabilized stream and pond access sites" *Agriculture and Environment Extension Publications*. 224. p. 2.

18 Haan, Matthew M.; Russell, James R.; Morrical, Daniel G.; and Strohbehn, Daryl R. (2007) "Effect of Grazing Management on Cattle Distribution Patterns in Relation to Pasture Streams," Animal Industry Report: AS 653, ASL R2205. p. 1.

19 Russell, J.R. (2012) "Site specific implementation of practices that alter the spatial/temporal distribution of grazing cattle to improve water quality of pasture streams in the Rathbun Lake watershed" Leopold Center Completed Grant Reports. p. 406.

So, why do farmers choose not to do this? The answer is simple: cost. For most farmers, "even if the costs of fencing and water systems are shared with government programs, the funding available for such programs is limited."[20] Those who are familiar with the industry recognize "the economic cost of placing and maintaining fences, providing alternative water sources, and the loss of grazing land."[21] The recommendations to farmers may be clear, but due to the economics of grazing and livestock production, many are unable to afford measures to protect water quality.

By contrast, at utility scale solar sites, fencing to restrict animal access to surface water is quite feasible. The panels and equipment themselves are positioned at a distance from ponds, riparian zones, wetlands, and other surface water. During construction of the site, permanent chain-link perimeter fencing is installed in all areas containing solar panels & electrical stations, whether grazing animals will be present on the site or not. These fences provide security for the equipment, prevent wild animals from damaging the panels, and protect any neighbors from electrical hazards present at a solar site. Because the need for fencing exists whether or not grazing animals are used for vegetation management, the solar company bears the responsibility and cost of fencing, not the grazier. Thus, solar graziers conform to best practices for water quality without incurring the burdensome cost of installing fencing. This simple step of fencing animals out of surface water—known as exclosure—generates the most significant positive benefit for water quality in areas where animals are grazed. As Tom Marshall from the National Environmental Research Council notes, "There are plenty of high-tech ideas to tackle pollution, but recent research suggests that some of the biggest gains in keeping our waterways clean could come from a more traditional technology—fences."[22]

Protect Riparian Buffer Zones

The second tool used to promote water quality in areas that are grazed is protection of riparian buffer zones. According to Thomas Isenhart of Iowa State University, "Riparian, or streamside, areas serve as a transition between upland pastures and waterways. In other words, they link pastureland with water. When these areas are managed to protect the waterway from any negative impacts of adjacent land use, they become buffers."[23] A primary cause of adverse effects from both grazing and agricultural tillage is nutrient and sediment runoff. The USDA considers runoff to be "the portion of the water produced by a storm event that does not enter the soil profile."[24] When the soil becomes saturated during a rainfall event, it no longer absorbs additional precipitation and this excess moisture instead travels overland. As this water flows, it can mobilize and transport soil particles, dissolved nutrients, manure (and associated bacteria), and other potential contaminants. These contaminants can negatively affect water quality if the runoff reaches a water body.

Riparian and coastal buffers represent fairly simple methods to prevent runoff from reaching a water body. By restricting access to areas directly adjacent to a water body and ensuring adequate vegetation, buffer zones filter potential runoff from fields, promote evapotranspiration, and provide additional temporal and physical infiltration and absorptive capacity.

Riparian buffers are extraordinarily effective filters of sediment runoff from agricultural lands. In fact, "several researchers have measured >90% reductions in sediment and nitrate concentrations in water flowing through the riparian areas."[25]

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20 Ibid. p. 406.
21 Ibid. p. 406.
22 Marshall, T. (2010, October 20). Fences reduce water pollution. National Environmental Research Council. https://nerc.ukri.org/planetearth/stories/847/.
23 Isenhart, T.M., Kovar, J.L., & Russell, J.R. (2008). A guide to managing pasture water: Streamside buffers." Agriculture and Environment Extension Publications. 222. p. 2.
24 United States Department of Agriculture, "Soil Health Info Sheet: Runoff and Erosion." Pastureland Soil Health.
25 Gilliam, J.W. (1994) Riparian wetlands and water quality. *Journal of Environmental Quality* 23:898.

By creating a barrier between pastureland and water bodies, riparian buffers prevent excess pasture nutrients and sediment from entering streams and ponds. Wendell Gilliam of North Carolina State University declares, "I consider riparian buffers to be the most important factor influencing non-point source pollutants entering surface water in many areas of the USA and the most important wetlands for surface water quality protection."[26]

Protecting riparian buffer zones around water resources is critical if grazing animals are in close proximity. Solar sites, meanwhile, are required by law to protect such buffer zones. When solar sites are permitted by state and local boards, they must meet conservation and environmental protection standards. These regulations protect wetlands by requiring a horizontal setback between the construction site and the water body. Because the installation of fencing is considered construction in most jurisdictions, the fencing is installed outside the buffer zone, and thus the animals are excluded from this critical area. Additionally, buffer zones for construction and industrial use are often far more restrictive (i.e. wider, or farther from the water body) than for agricultural uses, creating an even more robust buffer area. Solar sites are designed from the beginning with layouts that facilitate the protection of water quality. Fencing animals out of water bodies and riparian buffer zones is a requirement at solar sites because the construction requires it. These inherent design considerations and practices standard to solar power generation sites provide assurance that any solar grazing operation will by definition meet the two most important criteria for water quality protection.

Promote Vegetative Quality

To protect water quality near grazing operations, it is clear that restricting direct access to streams and ponds is critical. We have also seen that maintaining and enhancing riparian buffer zones is important in protecting against contamination from runoff. If these two measures alone are utilized, animals can be grazed on pasture near water bodies with minimal or negligible impact on important water resources. Beyond these protective measures, recent research in pasture management has recorded benefits to water quality that arise from pastures with well managed grazing systems. To explore this issue, we begin with an observation of the filtration qualities of plants and soil. Gilliam notes, "It has long been known that planted vegetative filters can be tremendously effective for removing sediment from surface runoff water."[27] The Leopold Center for Sustainable Agriculture reports that, "Vegetation can help prevent soil erosion and limit precipitation runoff, so maintenance of perennial vegetation on landscapes is a key to preventing pollution of surface water."[28] The recognition of perennial vegetation is important to note. In many agricultural systems, land is tilled, bringing bare soil to the surface and killing the vegetative cover. This process is common in agricultural cropping systems that produce annual grains and legumes for animal and human consumption. Even no-till systems that do not use mechanical action to turn the soil must sometimes kill otherwise healthy vegetation to prepare a seed bed for new crops.

Unlike row crop agriculture, the use of permanent pastures for grazing forage is generally less disruptive to soil health and vegetative cover. In systems that maintain permanent pasture cover without mechanical treatment and management of the pasture vegetation there is a much lower probability of sediment loss, non-point source pollution, and changes in hydrology. This continual vegetative cover makes permanent pastures a form of agriculture well suited to limiting sediment loss and surface water pollution. As the Leopold Center concluded, "maintaining perennial vegetation is a key to preventing sediment and nutrient loading of waterways."[29] Because many grazing operations utilize perennial pasture, this

26 Ibid.

27 Ibid.

28 Russell, J.R. (2012) "Site specific implementation of practices that alter the spatial/temporal distribution of grazing cattle to improve water quality of pasture streams in the Rathbun Lake watershed" Leopold Center Completed Grant Reports. p. 406.

29 Ibid p. 406.

form of agriculture is well suited to maintaining the ecological function of vegetative matter and protecting critical water resources. Seen in another way, perennial pastures act as expanded buffer zones, extending filtering and impeding runoff flow across the entire pasture. As we will see below, the permanent vegetative cover also prevents erosion and increases both the water holding and water filtering capacities of the soil.

Maintain and Promote Good Soil Health

Although perennial pasture excels at preventing silt, nutrients, and other pollutants from running off farmland and managed open space, there is a deeper benefit to this agricultural approach. The soils in healthy perennial pastures allow greater infiltration of water than bare or row-cropped soils, reducing the potential for runoff. To better understand this process, consider how infiltration affects runoff.

> Infiltration is the process by which water enters the soil and flows through the soil both horizontally and vertically. The rate of infiltration depends on many things. These include: soil texture, soil structure, bulk density (really a measurement of pore space), aggregate stability (how well groups of soil particles resist breaking down), organic matter, above ground plant leaves and stems, and the amount of roots in the soil. Soils with good soil health will allow much more of the water in a rainfall event to readily enter the soil profile than soils with lower soil health.[30]

During precipitation events, soils can become saturated, preventing additional infiltration and leading to runoff. Poor soils reach their saturation point more quickly—and more frequently—than healthy soils, but with enough precipitation, any soil can become saturated. By promoting soil health and vegetative cover, soils become more resistant to saturation and less prone to runoff.

Managing vegetation, avoiding compaction, and promoting management practices that promote increased soil organic content and carbon are important to managing and restoring soils that infiltrate well and have greater resilience.

> Soil organic matter is a key property that drives many important soil functions, e.g. supplying and cycling of nutrients; infiltrating, filtering, and storing water; sequestering C [carbon] from the atmosphere; and decomposing organic matter and xenobiotics. Stratification of soil organic matter with depth under various conservation agricultural systems was shown to influence water runoff volume and quality in studies across small plots, fields, and water catchments. Soil organic matter stratification with depth buffers soil and water quality against "normal" perturbations in agricultural systems.[31]

As we can see from the above, rich and healthy soil—similarly to dense and healthy vegetation—acts as a buffer to filter potential pollutants and promote water quality. Additionally, increasing the infiltration capacity and organic residues on the surface minimizes runoff.

> Accumulation of plant residues and organic carbon in the soil surface is also extremely important for protecting the off-site quality of surface waters in nearby streams and lakes. With increasing surface residue and soil organic C, the percentage of rainfall as runoff declines, soil loss declines, and nutrients lost in runoff declines.[32]

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30 United States Department of Agriculture, "Soil Health Info Sheet: Infiltration." Pastureland Soil Health.

31 Franzluebbers, A.J. (2008). Linking soil and water quality in conservation agricultural systems. *Journal of Integrated Biosciences* 6(1):15-29.

32 Franzluebbers, A.J. (2010). Will we allow soil carbon to feed our needs? *Carbon Management* 1(2), 241

By improving the quality of soils, specifically increased soil organic carbon (SOC), we can improve the quality of water. This ecological service provided by healthy soils is critical for both surface water quality and the health of subsurface waters that are filtered at various stages of the soil horizon. Now we'll see how well managed animal grazing can contribute to water quality by developing and enhancing soil health.

Actively Manage Animal Grazing

Conventional approaches to grazing view forage as a relatively endless resource to be harvested and the management focus is on maximizing animal weight gain per acre. This animal-centric approach does not often result in grazing that improves soil health, and can even degrade it. In the last few decades, animal graziers have paid increasing attention to soil and vegetation quality. In this new paradigm, soil and sunlight are recognized as the foundation for vegetation production and grazing is managed to optimize for soil and vegetative health. The key factor shaping the improvement of soil and vegetation is animal management. The use of the continuous grazing approach used by most graziers is now being supplanted by the use of evidence-based grazing management systems that result in higher yields and better overall land management. These approaches include systems such as rotational grazing, Management Intensive Grazing (MIG), conservation grazing, adaptive grazing, and Holistic Resource Management.

Although there are differences among these approaches, there is a common thread of intentionally managing animals to promote whole ecosystem health. Though it may be counterintuitive to those accustomed to viewing animals as a negative impact on water quality, recent research has demonstrated the opposite result, simply from utilizing proper animal management. A study published in the *Journal of Water and Soil Conservation* showed the change in perspective on soil health impacts when proper grazing management techniques are used.

> "Grazing strategies and stocking rates imposed for the past 11 years on this mixed grass prairie did not detrimentally affect soil organic carbon and nitrogen levels. The data, in fact, suggest that responsible grazing enhanced the overall soil quality as assessed by these parameters."[33]

By adopting proven grazing strategies, animal interactions with the land actually improve soil quality, which is directly correlated to positive water quality outcomes.

Not only do well-managed perennial pastures act as preventive controls on sediment loss and runoff, they increase the soil's capacity to hold water. Recent studies have examined the relationship between advanced grazing techniques and the increase in SOC, a reasonable proxy for soil organic matter. One study in *Nature* showed that "Moderate grazing enhanced SOC concentration by 12% in the upper 15 cm of soil."[34] As grazing animals deposit manure and urine and trample vegetative litter, these natural behaviors increase soil organic matter. Using SOC as a measurement tool, researchers have studied the relationship between soil organic matter and water quality ecosystem functions, finding that the presence of carbon is a critical indicator of soil health and corresponds to the benefits soil provides. In a 2010 report in *Carbon Management*, Franzluebbers notes,

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33 Manley, J.T., Schuman, G.E., Reeder, J.D., & Hart, R.H. (1995). Rangeland soil carbon and nitrogen responses to grazing. *Journal of Soil and Water Conservation* 50(3)

34 Hewins, D.B., Lyseng, M.P., Schoderbek, D.F, Alexander, M., Willms, W. D., Carlyle, C., Chang, S.X., & Bork, E. (2018). Grazing and climate effects on soil organic carbon concentration and particle-size association in northern grasslands. *Scientific Reports* 8(1), 1336 .
https://doi.org/10.1038/s41598-018-19785-1

> Soil organic carbon is a vital component of ecosystem properties, processes, and functions. It has highly relevant physical, chemical and biological features. This wide diversity of features has given soil organic carbon deserved attention as a key indicator of soil quality (i.e., how soil management affects the functioning of soil).[35]

In the same report, Franzluebber goes on to detail how three attributes of SOC affect soil and ecosystem properties. Low solubility of SOC slows leaching and increases retention of organic mater. SOC, itself, absorbs several times its mass in water through its effect on pore geometry and soil structure. And by binding to minieral particles to form water-stable aggregrates and improve water infiltration, SOC stabilizes soil structure.[36]

This research into grazing animals and soil health using ecological grazing methods is an exciting prospect for improving water quality at existing and future grazing sites. Through tactical animal management, graziers are able to increase soil organic matter and thereby enhance nutrient filtration, water retention, and water infiltration, thus preventing runoff. Rather than negatively impacting soil or water quality, properly managed grazing animals can be deployed as a significant tool to improve soil and water quality.

Solar Grazing and Water Quality at the Hecate Solar Site

Developments in hydrology, soil science, and grazing management have all contributed to a better understanding of the water quality impacts of grazing animals on permanent pastures. To understand how grazing animals at a solar site could impact nearby water bodies, we will consider the proposed Hecate 40 Megawatt solar power generation site in Coxsackie, NY. The site will be located on an existing 800-acre farm, of which 400 acres will be used for solar panels and related electrical stations. The 400 acres not intended for infrastructure installation are a mix of woodlands, wetlands or setbacks from roads, adjacent to neighboring properties, and buffer zones adjacent to water bodies or areas prone to flooding.

To understand the water quality impacts of this proposed solar site, let's examine the five elements reviewed above. The first element we covered is exclusion. At the Hecate site, initial construction plans indicate chain-link fencing on the perimeter of all panel installations and electrical stations. This installation is independent of vegetation management plans, so any potential grazing operation would already have fencing to exclude animals from streams, water bodies, and wetlands. This restrictive practice would address two critical factors to protect water quality. Additionally, state and local law require that fencing be installed outside buffer zones from wetlands. Any grazing animals on the site would necessarily be excluded both from water bodies and the wetland buffer zones. The simple installation of fencing, something integral to the construction of the site, would provide two critical factors influencing positive water quality outcomes.

Whether animals are utilized for vegetation management or not at this site, the installed infrastructure will assist in the improvement of adjacent water resources and downstream water resources such as Sleepy Hollow Lake. If animals were introduced for vegetative management, their presence could increase the water quality benefits through enhanced soil organic carbon. As Franzluebbers notes:

> Perennial pastures often contain a diversity of forages that grow during different parts of the year, and, therefore, offer extended root-growing opportunities for depositing carbon in soil. In addition, although perennial pastures are often grazed by ruminant animals, a significant amount of carbon contained in ingested plant material is actually returned to the soil as manure. Soil organic carbon sequestration with the establishment of perennial pastures

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35 Franzluebbers, A.J. (2010). Will we allow soil carbon to feed our needs? *Carbon Management* 1(2), 239.
36 Ibid.

> in the southeastern USA is highly significant. Compared with sequestration of soil organic carbon under conservation-tillage cropland, perennial pastures offer greater quantities and increased depth accumulation of soil organic carbon. Management-intensive pasture approaches may be able to sequester even greater quantity and depth distributions of soil organic carbon."[37]

As we saw above, SOC is a critical measurement tool correlated to water holding and infiltration capacity of soils. It's clear that grazing animals under a conservation or holistic grazing practice can lead to to an increase in soil organic carbon and water quality benefits, but what would increase the likelihood of this practice at the Hecate site? Article 10 of the New York Board on Electric Generation Siting and the Environment requires funding be provided by the solar site developer to develop a grazing plan for sheep used for vegetative management (NYS COMPTROLLER'S NUMBER: T101942). This plan, produced by a grazing specialist, will detail rotational grazing practices to promote whole system ecological health. If this plan is implemented, it will develop "high quality soil (that) protects the environment from degradation by reducing soil erosion and nutrient runoff (i.e., water quality protection)" and by storing carbon in soil and reducing greenhouse gas emissions.[38] The soil health benefits derived from the planned grazing of animals results in rich and stable soils that protect and even enhance water quality.

Although previous grazing practices could negatively impact water bodies, farmers and researchers have shown new approaches to grazing management that can both mitigate the negative impacts of grazing and actually improve soil health and water quality. This exciting development can provide mutually beneficial outcomes for both farmers and water conservation initiatives. At the Hecate solar site, best practices for water quality protection are integral components of the construction and maintenance phases of this project. If this solar site is developed and animals are used for vegetation management, research suggests that water quality in adjoining areas and downstream will not only be protected, but may even be enhanced.

37 Ibid p. 243.

38 Franzluebbers, A.J. (2008). Linking soil and water quality in conservation agricultural systems. *Journal of Integrated Biosciences* 6(1):17

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