EXTENSION

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Regenerative Agriculture: An Introduction and Overview

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Introduction

The term "regenerative" has gained popularity in the agricultural community and in food marketing programs over the past few years. The principles behind the regenerative movement reflect many of the recommended practices traditionally associated with the concept of sustainability. Many of these practices have been studied by scientists or practiced by agricultural producers for generations. A recent report by the California State Board of Food and Agriculture provides a succinct distinction between regenerative agriculture and sustainability efforts: "The 'regenerative' terminology is gaining traction and support like never before due in part to the belief that 'regenerative' moves beyond the philosophy of 'do no harm' to one of making things better." In this report, we review definitions for the regenerative agriculture concept, describe foundational practices specific to Oklahoma agriculture, and discuss published and ongoing research related to these practices.

Figure 1. Cattle grazing bermudagrass pasture. Photo by David Lalman.

What is Regenerative Agriculture?

There is not a universally accepted definition of regenerative agriculture [Newton et al., 2020; Schreefel et al., 2020]. In fact, Newton et al. (2020) reviewed 229 journal articles and 25 practitioner websites to characterize the term. These authors summarized that most definitions could be classified as process-based, outcome-based or a combination of the two. In their review, most process-based definitions included practices such as more intensive grazing management, reduced tillage, use of cover crops, reduction of fertilizer and herbicide/pesticide use, and integration of livestock and cropping systems. Outcome-based definitions included increases or improvements in biodiversity, carbon sequestration and soil organic carbon composition. Regenerative agriculture is often compared with conventional agriculture, although there is similarly no uniform definition of conventional agriculture [Sumberg and Giller 2022].

Soil Health

What is soil health?

The U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) defines soil health as the "soil's continued capacity to function as a vital living ecosystem that sustains plants, animals, and humans." Efforts to improve soil health are meant to provide additional benefits such as supporting clean air and water, diverse wildlife and beautiful landscapes. In some cases, all these functions can be achieved simultaneously. However, in many cases soils are suited for a subset of these uses. For instance, shallow, rocky soil on a steep slope is not suited for crop production

and may have limited capacity to grow grass for grazing. If these production goals are imposed on such a soil, they will likely result in erosion and eventually lower productivity. In addition, soil erosion pollutes nearby waters with sediment. In contrast, deep prairie soil is often well suited for crop production. However, if excess nutrients are applied to this system, along with tillage, it can pose a risk to water quality through erosion and off-site nutrient transport to surface and groundwater. Therefore, it is important to understand the characteristics of each site, its soil type and its condition. The NRCS Web Soil Survey provides guidance on soil characteristics throughout Oklahoma.[1]
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Is there any relationship between soil health, carbon sequestration and carbon footprint for crop and livestock operations?

One method of reducing atmospheric carbon, and thus mitigating global climate change, is to capture and store carbon in soil. This process is referred to as carbon sequestration. Removal of tillage from a crop production system will result in the accumulation of organic carbon in the near-surface soil (0 to 6 inches; [Cai et al., 2022, Nicoloso and Rice, 2021). In fact, soil carbon becomes more concentrated and stratified (more carbon near the soil surface) with more time under no-till management [Warren et al., 2019]. Despite the increase in soil carbon in this near-surface depth, there remains a high level of uncertainty about the net carbon sequestration that may occur after transitioning to no-till management. Cai et al (2022) analyzed 144 experiments comparing no-till versus cultivated systems in a review of the literature and found that when sampling depth was increased to 2 feet, no net sequestration of carbon was observed during 14 years after adoption of no-till. Nicoloso and Rice (2021) utilized 142 studies comparing no-till and cultivated systems and found similar results when crop frequency was the same. However, when cropping frequency was increased through adoption of double cropping or the addition of cover crops during fallow periods, they did observe significant increases in soil organic carbon. These findings are supported by those of Blonco-Canqui (2022) who analyzed 77 studies evaluating the impact of cover crops on soil organic carbon. In this study, it was concluded that adding high biomass (>1 ton/acre) cover crops to a cropping system resulted in increased soil carbon. Cover crops that did not produce 1 ton/acre of biomass did not significantly increase soil carbon in the top 12 inches of soil. This study concluded that delayed termination to allow for maximum biomass production is an important strategy when carbon sequestration is a goal for the cover crop program.

Sequestration of soil carbon attributed to cover crops is often used to assume that they reduce the carbon footprint of cropping systems. However, this is a simplified understanding of carbon footprints. A carbon footprint must be evaluated using a lifecycle analysis. The USDA defines life cycle analysis as a method of assessing the environmental impacts associated with all stages of a product's life. A life cycle analysis must include all inputs and outputs of a production system including raw materials and the processes used to create inputs and deliver outputs to the end user. Therefore, we cannot simply look at the accumulation or organic matter in soils as a net removal of carbon from the atmosphere. We must also consider the carbon footprint of the cover crop seed, its planting and termination in the life cycle analysis as we would the carbon footprint of the manufacturer of the chemicals and tillage operations used in a production system. This is a very complicated analysis, as such; published life cycle analysis available to fully understand the carbon footprint of cover crops versus no cover crop systems is not currently available.

No-till crop production seems to be another practice associated with regenerative agriculture. Is this practice sustainable, profitable and climate friendly?

No-till crop production dramatically reduces soil erosion in most systems. Currently, no-till management is applied to about 37% of cropland throughout the U.S. and about 34% of cropland in Oklahoma. Economic benefits stem from reduced labor and fuel costs when combined with diversification of crop rotation (No-Till Cropping Systems in Oklahoma E-966 Chapter 6). The climate benefits are thought to result primarily from the expected soil carbon sequestration resulting from no-till and reduced fuel requirements for no-till. However, lifecycle analyses of no-till versus conventional cropping systems are required to fully understand the climate benefits on a holistic basis. The removal from tillage does reduce fuel consumption, however some of this benefit is offset by the carbon footprint of pesticides and herbicides used in no-till systems. To date, no detailed lifecycle analysis is available for the diverse crop production systems in Oklahoma.

What is Oklahoma State University doing to help producers improve soil health?

OSU has provided soil sample analysis at a reasonable price to the public for decades. Each year, OSU's Soil, Water and Forage Analytical Laboratory analyzes more than 25,000 soil and plant samples sent in from farms, pastures and gardens around the state. These results are used to create recommendations that ensure the proper amount of fertilizer (organic and commercial) is applied to soils. Both over- and under-application have a significant impact on the soil health characteristics of a landscape. The recommendations used are based on a historical and ongoing research program conducted by OSU scientists (Soil Fertility Handbook E-1039; Oklahoma Forage and Pasture Fertility Guide E-1021).

A significant environmental and economic concern is the application of nitrogen (N). OSU is a leader in the development and implementation of technologies that have and will continue to greatly improve the efficiency of applied nitrogen. One such technology is the N-Rich Strip and Sensor Based Nitrogen Rate Calculator (CR 2277 Applying Nitrogen Rich Strips, PSS-2278 Using the GreenSeekerTM Handheld Sensor and Sensor-Based Nitrogen Rate Calculator), which is made available at no cost through OSU.

Unique to OSU are the long-term fertility trials, such as the Magruder Plots, which were established in 1892. These plots, along with many others, were developed in the late 1960s, and provide researchers insight into long-term application of nutrients such as manure and commercial fertilizer.[1]

Similarly, OSU has conducted research and demonstration on the utilization of no-till management for over 20 years to help crop producers improve soil health by reducing erosion on croplands. Although erosion control was the primary goal of this effort, secondary benefits of no-till include improved soil water dynamics resulting from reduced near-surface soil temperature and water evaporation from these systems, which increases the success of summer crops planted into surface residues from the prior crop. Inclusion of cover crops can be important in systems where cash crop residues are limited in their ability to protect the soil surface from wind and water erosion and the detrimental impact of radiation, which increases soil temperatures and drives evaporation from the soil surface (No-Till Cropping Systems in Oklahoma E-966).

More recently, OSU scientists have developed practical soil health assessment tools. These efforts go beyond the many years of research invested in studying soil chemical properties and nutrient needs of plants. The more recent developments will provide practical methods for farmers and ranchers to evaluate the impact of their management practices on soil's physical (soil aggregation) and biological (CO2 burst) characteristics.

Water

How do regenerative agriculture practices affect agricultural water availability and water quality?

Several elements of regenerative practices may affect agricultural water availability and quality. It is well documented that keeping the soil covered and minimizing soil disturbance (both key elements of regenerative ag practices) reduce erosion and the runoff of sediment and nutrient-laden water to nearby bodies of water. Furthermore, some researchers have also found that farming systems that maintain a permanent soil cover, minimize soil disturbance and diversify crop/plant cover can increase soil water storage through better soil aggregation and improved soil structure [Panagea et al., 2021]. However, the impact of regenerative practices on soil water retention and water quality varies. Some of these factors include soil texture, preexisting soil carbon, and climatic conditions [Rawls et al., 2003].

OSU is working with Texas A&M and other universities to evaluate regenerative agricultural practices in the Southern Great Plains. Using experimental data collected through the project, along with historical and future climate projection data, we are assessing the long-term effects of these practices on soil health, water capture, greenhouse gas emissions, watershed-scale processes and climate change adaptation.

How do cover crops affect soil moisture for the next crop?

Soil moisture availability is very much dependent on the rainfall pattern experienced by each system and the surface residue that would be available without the cover crop included in the rotation. Therefore, the impact of cover crops on soil moisture dynamics for the next crop is highly variable. Cover crops transpire soil water while they are growing. The larger they grow (more biomass) and the longer they grow, the more soil water they will consume. However, the residue they leave behind protects the soil surface from crusting and thereby increases infiltration of subsequent rainfall. Increased dryness after cover crop growth also contributes to the increased infiltration. In production environments where adequate rainfall is received after termination, soil moisture can be similar or even greater in cover crop treatments [Basche et al, 2016]. Research conducted in semi-arid climates like those in western Oklahoma has shown that cover crops can increase the collection and storage of moisture after termination, but that moisture availability at planting of the cash crop can still be lower in the cover crop treatment when compared to a fallow treatment. For example, in one experiment, the cover crop treatment had lower soil water content, which resulted in reduced wheat yield (Nielsen, et al., 2016).

Oklahoma has a high diversity of growing environments due to precipitation gradients from east to west. In addition, extreme variability in year-to-year rainfall patterns within a region adds to the uncertainty of the influence of cover crops on soil moisture that will be available for the cash crop. Therefore, it is difficult to consistently predict the impact of cover crops on soil water availability for the following crop. We can only say for sure that the greatest likelihood of benefit will be experienced in systems with low residue conditions where sufficient cover crop biomass can be grown quickly and terminated before planting the cash crop to allow for some recharge of the soil moisture.

Grazing Management

"Adaptive Grazing Management" is key to regenerative agriculture. What do these terms mean and what do we know

about the effectiveness of these strategies compared to more traditional practices such as continuous stocking?

Adaptive grazing management is a process-base management approach where livestock producers make management decisions to achieve specific goals. Monitoring pastures and animals is essential since landowners make management changes when goals are not met. The full process includes:

- Set specific goals for your land and livestock.
- Plan strategically by taking into consideration your resources, skills and labor.
- Monitor resources for specific thresholds.
- Act when thresholds are met.
- Evaluate whether current management practices are meeting established goals.
- Adjust your plan or goals as needed.

Many different types of grazing management strategies fall under adaptive grazing management. What is consistent between them is that managers are regularly reevaluating whether their management is achieving the goals they have set [Derner et al. 2022]. In Oklahoma pastures, the management decision that has the greatest impact on grazing land sustainability [Gillen et al. 1991, 1998], livestock performance and economic sustainability is stocking livestock according to the productivity of the land [McCollum et al. 1999].

Management intensive grazing is also a broad term used for many different grazing systems. What is consistent between these systems is that managers divide pastures into multiple paddocks and while livestock graze certain paddocks, other paddocks are withheld from grazing for a rest period. The number of paddocks and herd density (number of animals per unit of area) can vary between approaches but in all methods, managers rotate herds from one paddock to the next repeatedly. Strip grazing, limit grazing, mob grazing and rotational grazing are all types of management intensive grazing systems. There is an emphasis on the management being intensive and not necessarily the grazing under this approach [Dowhower, 2019].

Adaptive multi-paddock (AMP) grazing is a short-duration rotational grazing system where animals graze in dense herds. This approach typically involves grazing each paddock for hours to days until livestock have consumed no more than about 50% of available forage. The manager then rests paddocks from grazing for sufficient time to allow vegetation regrowth. The grazing and rest duration as well as stocking rate is adapted to the rate of vegetation growth as it changes throughout the year and between years. Managers are also advised to avoid using herbicides, pesticides and fertilizers [Mosier et al. 2021].

Adaptive management is key to sustainable grazing management with benefits to plants, animals and long-term profitability. Some research has compared adaptive rotational grazing practices to non-adaptive continuous grazing, and it is difficult to know whether the adaptive management or the rotational grazing is contributing to grazing outcomes. Research comparisons between adaptive multi-paddock rotational grazing and continuous grazing in the Southern Great Plains are prevalent, especially in Oklahoma. Rangeland ecologists, plant ecologists, animal scientists and soil scientists have studied how native plant communities, soils and livestock respond to different management strategies.

Impact on Soils

A recent eight-year study in El Reno, Oklahoma, examined the effects of continuous grazing and adaptive multi-paddock rotational grazing on soil carbon, nitrogen, microbial biomass, soil respiration and biological activity. Rotational pastures were divided into 10 paddocks with cattle moved as one herd to create greater stock density in the rotational pastures versus the continuously grazed, undivided pastures. No differences were found between the two grazing methods for total soil nitrogen, carbon or particulate organic carbon at any depth (0-12 inches) or for soil microbial biomass, basal soil respiration or soil biological activity in the study. They concluded that both grazing management strategies preserved important soil properties, and variability within paddocks was much greater than the differences found between grazing systems [Franzluebbers et al. 2019].This is consistent with other research where variability in rangeland pastures has made it difficult to find consistent results from grazing treatments.

A Marietta, Oklahoma, study by the Noble Research Institute also examined impacts of stocking densities on soil over 10 years. Researchers examined three levels of stocking density and its impacts on soil bulk density, soil resistance to penetration and water infiltration rate. The three levels of stocking density were five yearling stockers per acre for 36-48 hours (light), 10 stockers per acre for 24 hours (moderate) and 20 stockers per acre for 12 hours (high). Stockers grazed paddocks four to six times from April through October with rest periods ranging from 35 to 60 days. The researchers found that greater stock densities increased soil bulk density and resistance to penetration while decreasing water infiltration rates. They concluded that this could lead to "… an increase in surface runoff and erosion. Ultimately, this can lead to the loss of pasture acreage by soil surface degradation and economic decline by the resulting loss of forage production" [Daniel et al. 2002].

Impacts on Animals

An OSU study in north-central Oklahoma compared livestock performance of yearlings grazing continuously versus those in adaptive multi-paddock rotational grazing. Managers kept yearlings in rotational treatments in a single herd to maximize stock density. Managers adjusted grazing and rest periods to match forage growth. Researchers tracked gain per animal, gain per acre and net return per acre. Over the five-year study, they found individual season-long yearling gains were 29-48 pounds less under adaptive multi-paddock rotational grazing than for yearlings grazing continuously. Individual yearling gains were 11%–20% lower in adaptive multi-paddock rotational pastures than continuously grazed pastures with the greatest reductions seen in heavily stocked rotational pastures. Steer diets and forage standing crop measurements indicate these lower gains were due to lower forage intake in rotational yearlings. Forage crude protein in the rotational yearling diets was lower (7.7%) than for continuous steers (9%), likely due to rotating to more mature grass stands rather than continuing to graze in the same pasture. Gains per hectare were greater for continuously than rotationally grazed pastures at all stocking rates. Even at the heavier stocking rate, where gains per acre should be maximized, continuously grazed yearlings gained 252 pounds per acre versus adaptive multi-paddock rotationally grazed yearlings 202 pounds/acre over the 150-day grazing season. They found that under no stocking rate would rotational stocking provide the net returns equal to those attained with continuous stocking at a conservative stocking rate. Variable cost per head in rotational pastures would have to decrease by 24%–34% to equalize net returns. This was with no additional fencing or water development cost included. They concluded that unless the decline in weight gain could be reduced, there is no economic incentive for rotational grazing under these conditions [McCollum et al. 1999].

The responses to grazing management may change with different forage systems and management systems. Research with beef cows grazing an introduced warm-season perennial bermudagrass forage base compared performance and economics of continuous grazing at a moderate stocking rate versus rotational grazing at a similar stocking rate or a high stocking rate of twice the moderate stocking rate [Beck et al., 2016]. The research was also designed to allow for integration of other forage management activities where possible in the rotational grazing management system, including stockpiling of warm-season grasses and interseeding of cool-season annuals. All pastures were fertilized according to soil tests to stimulate forage growth at appropriate times for higher forage needs. This research indicated that integration of rotational grazing management resulted in decreased weaning weights per calf by 22 pounds at the moderate stocking rate and by 40 pounds at the high stocking rate. Increasing stocking rate with rotational grazing increased total calf weaning weight per acre by 89% compared to either moderate stocking rate with rotational or conventional grazing management. The total number of days of hay feeding were 106 for the conventional grazing management compared with 37 days for the high stocking rate rotational grazing and 15 days for the moderate stocking rate rotational grazing. Pregnancy percentage and calving rates were not affected by grazing management. In this analysis, net return per acre was similar for continuous and rotational grazing at the moderate stocking rate, indicating the costs of increased management in the rotational system offset the cost of longer hay feeding season for the continuous grazing system. Net returns per animal were greater for the rotational grazing system with increased stocking rates by reducing winter feeding requirements and increasing carrying capacity. This study underlines the need for producers to have a clear objective for their grazing management system and to carefully evaluate research based on those objectives.

Can multi-species grazing be used to sustainably increase grazing productivity in a livestock enterprise? How does this practice influence invasive brush species?

Multi-species grazing can incorporate any combination of at least two different species of livestock. OSU is currently investigating the combination of cattle and goats to combat woody plant encroachment in north-central Oklahoma. Researchers evaluated the effects of goats on cattle diet selection in diverse, woody plant encroached pastures. Seasonal differences were identified between goats and cattle. Goats selected 20% more forbs in spring than cattle, while cattle selected 20% more forages during winter months. Cattle also consumed 40% more legumes in summer, while goats selected 40% more woody plants than cattle in both winter and summer [Lippy et al., 2024]. Cattle were not impacted by goat grazing pressure due to different diet selection preferences. Multispecies grazing does not drain the land of its resources because each animal is able to utilize different plants more efficiently [Hintze et al. 2021]. In production systems where woody plant encroachment is extreme, grazing goats with cattle may increase rangeland carrying capacity by 70% because goats prefer brush and browse species while cattle prefer grasses [Walker, 1994].

Does cattle breeding and selection have a role in regenerative agriculture?

Cattle are a critical component of a sustainable and secure food production system. Most of the beef production cycle occurs on land not suitable for raising crops. For perspective, of the 2.3 billion acres available in the U.S., about 655 million acres (29%) are classified as grassland pasture and rangeland, and 316 million acres (14%) are identified as parks and wildlife areas, some of which are grazed [Economics Research Service, USDA ARS 2017]. Beef is a highly digestible and nutrient-dense protein source for humans. Human beings lack the digestive system needed to survive on soil or fibrous plants. Grazing cattle, equipped with a ruminant digestive system, function as an intermediary, turning sunlight, carbon dioxide and water into a nutritious, delicious and sustainable food source.

Beef cattle selection and breeding systems that result in sustainable, economical improvements in land resource utilization are critical to improving ranch profitability, food security and beef production's carbon footprint. For example, using a planned crossbreeding system results in direct and maternal heterosis in the cow herd. This heterosis (hybrid vigor) is achieved through non-additive genetic effects gained by crossing purebred parents. Maternal heterosis increases reproductive efficiency and cow longevity. Thus, when a planned crossbreeding system is implemented, pounds of calf weaned per cow exposed (to breeding) increases. This improvement in productivity per cow is produced with little to no additional feed or forage inputs. In one classical experiment [Cundiff et al., 1992], crossbred cows produced 30% more cumulative calf weaning weight (511 pounds) in a 12-year period compared to purebred Hereford, Angus or Shorthorn cows.

Better purebred seedstock produce better crossbred animals. Modern genetic prediction offers several genetic values, which can be used to improve the efficiency, sustainability and profitability of beef production. For example, selection pressure to achieve a cow herd with less mature weight, more direct weaning growth, increased reproductive efficiency and moderate maternal milk should result in a cow herd requiring fewer inputs while remaining highly productive.

Ongoing research at OSU is working to identify animals that are more efficient at converting forage to beef. Cattle that excel at forage utilization should require fewer forage and concentrate supplement resources in the beef production process.

Backyard Production Systems

There are many different backyard production systems. A few examples include horticulture, vegetable gardening and poultry production. Are there opportunities for these systems to contribute to regenerative agriculture?

Horticulture and Vegetable Gardening

In backyard systems like home horticulture and gardening, many simple approaches apply to regenerative agriculture practices. In vegetable production and flower gardening, the Earth-Kind Gardening fact sheet series can help home gardeners learn about how to use alternative pest control methods to pesticides such as improved cultural techniques and the use of "softer" pesticides. Information on the use of Integrated Pest Management (IPM) available in many of OSU's horticultural pest management fact sheets also increases the chances of success of pest control with less pesticide usage. By reducing pesticide usage in the garden and landscape we can hope to increase beneficial insect populations, including pollinators. Pollinators can also be encouraged in gardens by planting appropriate nectar and food plants, including many natives recommended in our fact sheets.

Reducing cases of excessive fertilizer application in urban and suburban lawns and gardens can reduce runoff of nutrient-laden water to nearby bodies of water. Monitoring soil nutrients and applying appropriate types and amounts of fertilizer to lawns and gardens is one simple method to dramatically reduce excessive fertilizer use and thus, improve water quality near urban areas. Nutrient-precision lawn fertilization can also reduce the use of herbicides by allowing properly managed turfgrasses to out-compete weeds.

Cover cropping for backyard gardeners can help to build organic matter in traditional low organic matter Oklahoma garden soils. This restorative practice involves improving garden soils using summer and winter cover cropping/green manure crops used on fallow areas and then incorporated before the next growing season. Composting is another good way to increase organic matter in garden soils. And by recycling garden and yard waste, consumers can also reduce household solid waste flow.

Research-based information on selecting low-water-use trees, shrubs and bedding plants that require less irrigation in the landscape can be very helpful when planning a low-water-use landscape.

Using mulches in the garden and landscape will also reduce watering needs. Another water-saving horticultural practice is the use of drip irrigation systems, which significantly reduce water usage in home landscape beds and gardens.

Poultry Production

Small flocks of chickens have been present in rural America for decades, but interest has increased substantially in the past decade. Theories abound around the reason for the increase in poultry ownership, including the idea of solving local food insecurity to increasing the knowledge of food sources to owning poultry as non-traditional pets. Backyard poultry production can contribute to regenerative practices. First, backyard flocks of poultry can be a type of recycler for the household, consuming kitchen waste while reducing the solid waste produced by the household. Limited to 10% of their overall diet, chickens can utilize this kitchen waste as a food source to produce eggs or meat. Because chickens devour insects, beetles and grubs, they are an excellent alternative to using pesticides for this purpose. After proper composting methods, poultry litter (manure) can be a safe fertilizer to increase soil nutrients, complementing vegetable production. To bridge the gap of knowledge for poultry owners, OSU Extension offers in-person training, online resources and an online course about basic backyard poultry production.

Through poultry ownership, people who are several generations removed from agriculture can learn about their food supply. Connecting agriculture to the people it serves should continue to be an important aspect of food production. Backyard poultry keeping, gardening and other small scale agricultural production practices continue to maintain small scale food production and associated regenerative agricultural practices.

Conclusion

To date, there has been no standard definition adopted for the regenerative agriculture movement therefore, interpretation of the term continues to vary widely. Definitions can generally be classified as process-based, outcome-based or a combination of the two. The idea of sustainable agriculture was largely seen as an effort to "do no harm" while the concept of regenerative agriculture advocates for practices that should result in "making things better." Most programs or researchers advocate for practices that result in improved soil health and reducing or minimizing the use of synthetic fertilizer, herbicide and pesticides. While improved soil health is broadly accepted as an outcome of regenerative agriculture, soil characteristics vary drastically from site to site. At the same time, regional climate varies dramatically within Oklahoma. For these reasons, practices intended to "regenerate" agriculture at a given site must be carefully evaluated.

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