Vermont Legislative Research Service

http://www.uvm.edu/~vlrs/

Regenerative Soils: Practices and Market Potential

(Posted on May 16, 2017)

In response to Vermont Senate Bill 43 (S.43), “An act relating to establishing a regenerative soils program,” this report describes regenerative agriculture, examines its prevalence internationally, and considers potential market reactions to the bill’s proposed food-labeling measure.[1] S.43 also proposes the creation of a working group “to evaluate the viability and potential impacts of a regenerative soils program in the state.”[2] According to a co-author of the bill, a regenerative soils certification program in Vermont would be the first of its kind in the United States.[3] Due to the novelty of regenerative agricultural policy, the scope of academic research and news coverage on the topic is limited.

Overview of Regenerative Agriculture

Farming systems can be classified on the extent to which they rely on external inputs. Traditional agricultural approaches are referred to as “open” systems because they rely on large levels of outside inputs, including fertilizers, pesticides, and mechanical energy.[4] The soil used in open systems becomes depleted, and without outside inputs, these procedures cannot sustain profitable production levels.[5]

---

1 “An act relating to establishing a regenerative soils program,” Vt. S.43 (2017).

2 Ibid.

3 Vermont’s Regenerative Agriculture Certification Program, Studio Hill Farm, accessed May 1, 2017, http://studiohill.farm/wp-content/uploads/sites/10/2016/01/BillS.1592016-RegenerativeAg1.pdf. In the noted document, Jesse McDougall, a Vermont farmer and co-author of S.43, states that a regenerative soils certification program would be the first of its kind in the world.

4 Christopher J. Rhodes, “Feeding and Healing the World: Through Regenerative Agriculture and Permaculture,” *Science Progress* 95 (2012): 345-446, accessed April 25, 2017, http://www.ingentaconnect.com/content/stl/sciprg/2012/00000095/00000004/art00001.

5 Ibid.

Regenerative agricultural practices include many well-known sustainable farming practices. Some examples are increasing crop diversity, rotating crops, and using organic fertilizers.[6] Regenerative agricultural approaches minimize external inputs with the goal of keeping the soil healthy so the system can function sustainably and as independently as possible.[7] With these "semi-closed" procedures, there is minimal reliance on external inputs such as fertilizers, because the soil itself supplies most of its required nutrients.[8] These approaches use less energy overall, including less machinery, fertilizer, herbicides, and transport, and are more energy efficient.[9] Proponents argue that this enables them to better balance food production with their environmental impacts when compared to more traditional agricultural practices, which require significant outside resources.[10] Regenerative systems are typically referred to as "semi-closed" instead of "closed," because farms that utilize such procedures are not completely self-contained, as they sell their products to outside consumers.[11]

Among other environmental benefits, proponents of regenerative soil practices show that these techniques can maximize carbon fixation, contributing significantly to broader carbon sequestration efforts.[12] Carbon fixation is the general process by which plants take carbon from the air, store it, and use it for their own energy production.[13] According to the Rodale Institute, which advocates for sustainable agriculture, these practices have the potential to sequester nearly 100 percent of global carbon emissions.[14] The French Ministry of Agriculture's "4 pour 1000" initiative makes a similar argument in favor of regenerative agriculture. The name of the initiative, 4 per 1000, refers to the fact that a 0.4 percent annual growth rate in soil carbon would be enough to stop the increase in atmospheric CO_2.[15]

Regenerative systems are more energy efficient than their conventional counterparts, but they are also more labor intensive.[16] While this demand could have positive impacts on local economies, the comparatively high labor requirement of regenerative practices remains a significant obstacle.[17]

---

6 Andreas Gattinger et al., "Enhanced Top Soil Carbon Stocks Under Organic Farming," *Proceedings of the National Academy of Sciences of the United States of America* 109 (2012): 18226–18231, accessed May 9, 2017, http://www.pnas.org/content/109/44/18226.

7 Craig J. Pearson, "Regenerative, Semiclosed Systems: A Priority for Twenty-First-Century Agriculture," *Bioscience* 57 (2007): 409-418, accessed April 25, 2017, https://academic.oup.com/bioscience/article-lookup/doi/10.1641/B570506.

8 Ibid.; Rhodes, "Feeding and Healing the World," 345-446.

9 Pearson, "Regenerative, Semiclosed Systems," 409-418.

10 Ibid.

11 Rhodes, "Feeding and Healing the World," 345-446.

12 Rodale Institute, *Regenerative Organic Agriculture and Climate Change: A Down-to-Earth Solution to Global Warming* (Kutztown: Rodale Institute, 2014): 1-24, accessed April 25, 2017, https://rodaleinstitute.org/assets/WhitePaper.pdf.

13 New Oxford American Dictionary, 3 ed., s.v. "carbon fixation."

14 Rodale Institute, *Regenerative Organic Agriculture and Climate Change*, 2.

15 "4 pour 1000," Ministry of Agriculture, France, accessed April 22, 2017, http://4p1000.org/.

16 Pearson, "Regenerative, Semiclosed Systems," 413.

17 Ibid.

Sequestering Carbon vs. Green Power Generation: Comparing Regenerative Soil Practices with Solar Power

Different types of land usage, such as forest, cropland, wetland, or developed land have differing potentials to sequester carbon.[18] As noted above, regenerative agricultural practices have significant potential in this area.[19]

Agriculture and Forested Land Carbon Sequestration

Studies estimating the potential carbon storing abilities of different types of land use have found that normal unrestored cropland can sequester between 300 and 500 kilograms of carbon, per hectare, per year (kg C/ha/y); unrestored grazing land can sequester 40-200 kg C/ha/y; and, forested land can sequester about 110-430 kg C/ha/y.[20] Restored soils, however, can store significantly more carbon, about 400-800 kg C/ha/y.[21]

Solar

Proponents of regenerative agriculture might be interested in the efficacy of other land uses that have the potential to offset carbon. One such land use, which interests the authors of S.43, is solar power. Calculating the potential carbon savings of solar panels is complicated. The relevant factors include commercial versus residential installations, regional CO_2 emissions per megawatt hour (MWh), average yearly energy use per house, and the specific system installed.[22]

Residential Solar

An average Vermont house uses 560 kilowatt hours (kWh) of electricity per month, or 6,720 kWh/year.[23] The average CO_2 emissions per MWh are 329.31 kg in New England, while in Vermont the average is only 95.25 kg; Vermont's high proportion of renewable energy sources

---

[18] Adam Chambers, Rattan Lal, and Keith Paustian, "Soil Carbon Sequestration Potential of US Croplands and Grasslands: Implementing the 4 per Thousand Initiative," *Journal of Soil and Water Conservation* 71 (2016): 68A-74A, accessed May 3, 2017, http://www.jswconline.org/content/71/3/68A.

[19] Ibid.

[20] Ibid; Rattan Lal, R. F. Follett, and John M. Kimble, "Achieving Soil Carbon Sequestration in the United States: A Challenge to the Policy Makers," *Soil Science* 168 (2003): 827-845, accessed May 3, 2017, https://archive.org/stream/745281-soil-carbon-amp-challenes-to-policy-makers/745281-soil-carbon-amp-challenes-to-policy-makers_djvu.txt; Linda S. Heath et al., "The Potential of US Forest Soils to Sequester Carbon," in *The Potential of US Forest Soils to Sequester Carbon and Mitigate the Greenhouse Effect,*" ed. John M. Kimble et al. (Boca Raton: CRC Press, 2003): 385-394, accessed May 3, 2017, https://www.fs.fed.us/ne/newtown_square/publications/other_publishers/ne_2003heath01p.pdf

[21] Lal et al., "Achieving Soil Carbon Sequestration in the United States," 837.

[22] "Tree Math 2: Solar vs. Trees, What's the Carbon Trade-off?" *The Energy Miser*, last updated September 24, 2015, http://newenglandcleanenergy.com/energymiser/2015/09/24/tree-math-2-solar-vs-trees-whats-the-carbon-trade-off/.

[23] Patricia Richards (General Manager, Washington Electric Cooperative), in discussion with an author, May 2, 2017.

results in lower levels of carbon emissions per kWh.[24] As Vermont produces only about 40 percent of the energy it consumes, however, the state relies on out-of-state energy.[25] The Environmental Protection Agency (EPA) estimates that New England has an annual base load output of 262.27 kg/MWh of carbon, and 430.32 kg/MWh of carbon at peak hours.[26] Because of this variance, this report will only consider the EPA's New England peak average.

Assuming an installed solar unit produces exactly 6,720 kWh/year, and using the EPA's peak New England carbon emissions rate of 430.32 kg/MWh, carbon emissions are reduced by 2,891.75 kg/year.[27] Most residential solar panels are installed on rooftops rather than on the land, which makes it challenging to compare their carbon mitigation impacts with regenerative soil practices.

Commercial Solar

A small photovoltaic solar power plant (defined by the National Renewable Energy Laboratory as producing between 1 and 20 MW) takes up approximately 8.3 acres/MW (3.4 hectares), on average.[28] Given the average Vermont farm size of 171 acres—and assuming all of that land is useable, that the solar panels are positioned at an optimal angle, that there is no shade or soiling of the panels, and that the panels receive an average of 3.5 hours of peak sun each day—a 171-acre solar installation could offset as much as 163,665.38 kg C/hectare/year.[29]

---

24 "2014 ISO New England: Electric Generator Air Emissions Report," *ISO New England*, last modified January 2016, https://www.iso-ne.com/static-assets/documents/2016/01/2014_emissions_report.pdf; "Nuclear and Uranium," U.S. Energy Information Administration: Independent Statistics and Analysis, accessed May 14, 2017, https://www.eia.gov/nuclear/state/archive/2010/vermont/. This 2014 estimate includes energy produced by Vermont Yankee Nuclear Power Plant, which used to generate a significant portion of Vermont's electricity and is no longer active.

25 "Vermont: State Profile and Energy Estimates," *US Energy Information Administration*, last modified June 16, 2016, https://www.eia.gov/state/analysis.php?sid=VT; "Electric Generator Air Emissions Report," *ISO New England*.

26 "eGRID2014 GHG Annual Output Emission Rates," Environmental Protection Agency, accessed May 1, 2017, https://www.epa.gov/sites/production/files/2015-10/documents/egrid2012_ghgoutputrates_0.pdf. Unlike the ISO New England estimation, the EPA separates base load and peak carbon emissions, because utilities use different energy sources during peak hours to accommodate the increased demand.

27 Richards, discussion; "eGRID2014 GHG Annual Output Emission Rates."

28 Sean Ong et al., "Land-Use Requirements for Solar Power Plants in the United States," *National Renewable Energy Laboratory*, accessed May 1, 2017, 10, http://www.nrel.gov/docs/fy13osti/56290.pdf.

29 Sean Ong et al., "Land-Use Requirements for Solar Power Plants," 10; "2016 State Agriculture Overview: Vermont," United States Department of Agriculture, National Agricultural Statistics Service, accessed May 1, 2017, https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=vermont; "Solar Electric Design Primer," *Vermont Solar Engineering*, accessed May 9, 2017, http://www.vermontsolar.com/solarprimer_design_analysis.html; "Key Factors for Solar Performance," *SunPower*, accessed May 9, 2017, https://us.sunpower.com/sites/sunpower/files/media-library/white-papers/wp-key-factors-solar-performance.pdf; Calculations used to get estimate: 171 acres/8.3 acres per MW = 20.6024 MW; 20.6024 MW multiplied by 3.5 hours of sunlight = 72.1084 MWh/day; 72.1084 MWh/day multiplied by 365 days in a year = 26,319.5783 MWh/year. 26,319.5783 MWh/year multiplied by 430.32 kg C/MWh = 11,325,840.93 C/year; 11,325,840.93 C/year/69.2012 hectares = 163,665.38 kg C/hectare/year.

The potential greenhouse-reduction benefits of solar power vastly exceed those of regenerative agricultural practices. The production of solar panels is, however, an energy consuming and greenhouse gas producing process, which until recently, made it a net energy sink.[30] Current estimates find photovoltaic units produce 20-25 kg of carbon/MWh, and take approximately one year to pay off their energy debt.[31] Additionally, given Vermont's agricultural tradition and interest in local food production—plus the cost of solar installation—it is unrealistic to expect all farms to convert all or even some of their land to solar. A combination of improved soil practices and increased renewable energy generation would be the optimal approach.

Regenerative Agricultural Practices in Other Countries

France

In 2015, the French government created the 4 per 1000 initiative to address climate change and food security.[32] The program, which was officially announced during the 2015 United Nations Climate Change Conference in Paris, aims to bring together scientists, government, and businesses to implement voluntary farming practices that maintain, enhance, and preserve soil carbon.[33] As stated above, the name of the initiative refers to the fact that a 0.4 percent annual growth rate in soil carbon would be enough to stop the increase in atmospheric CO_2.[34] In 2014, there were 32.4 billion tons of global carbon emissions from fossil fuels, while 1500 billion tons of organic carbon are stored in soil.[35]

France has also committed to "The Agroecology Project," which began in 2012 and aims to have a majority of French farms using agroecology by 2025.[36] Agroecology is described by the French Ministry of Agriculture as a systematic approach to food production aimed at increasing resilience and sustainability, using ecologically sound farming practices such as planting buffers, rotating crops, cover cropping, and reducing use of chemical fertilizers.[37] The program emphasizes farmer training, scientific research, and increasing public support, but does not specify how farmers should be participating.[38]

---

30 Atse Louwen et al., "Reassessment of Net Energy Production and Greenhouse Gas Emissions Avoidance after 40 Years of Photovoltaics Development," *Nature Communications* 7 (2016), accessed May 9, 2017, https://www.nature.com/articles/ncomms13728.

31 Ibid.

32 "4 pour 1000," Ministry of Agriculture, France, accessed April 22, 2017, http://4p1000.org/.

33 Ibid.

34 Ibid.; Todd A. Ontl and Lisa A. Schulte, "Soil Carbon Storage," *Nature Education Knowledge* 3 (2012): 35, accessed April 30, https://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790.

35 "4 pour 1000"; "CO2 Emissions from Fuel Combustion: Highlights," International Energy Agency, accessed April 23, 2017, http://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustion_Highlights_2016.pdf; Ontl and Schulte, "Soil Carbon Storage," 35.

36 "Agroecology in France," Ministry of Agriculture, France, accessed April 27, 2017, http://agriculture.gouv.fr/sites/minagri/files/1604-aec-aeenfrance-dep-gb-bd1.pdf.

37 Ibid., 3.

38 Ibid., 1.

Australia

Australia has incorporated carbon sequestration practices into its National Standard for Organic and Bio-Dynamic Produce.[39] The Standard lists general principles as well as specific minimum standards for products to be sold as organic.[40] In its section on soil management, the Standard states that "sufficient organic material should be regenerated and/or returned to the soil to improve, or at least maintain, humus levels"; this standard is similar to that of U.S. organic certification requirements.[41] Humus is the "organic component of soil, formed by the decomposition of leaves and other plant material by soil microorganisms."[42] The Australian guidelines also include provisions for limiting the use of non-renewable resources and outside fertilizers with the goal of creating closed systems.[43]

Consumer Awareness and Market Potential

One of the stated purposes of the proposed working group in Vermont's S.43 would be to "evaluate any economic impacts of a regenerative soils certification program, including whether a global market exists for products and goods produced through regenerative soils practices."[44] Any such evaluation would substantially contribute to the field of research on regenerative agriculture, as market researchers have not yet explored the possible demand for products made using regenerative soils practices. This absence of research strongly suggests that consumer awareness of regenerative agricultural practices is limited. There is, however, a much wider body of market research on other food certification labels, such as "organic" and "non-GMO."[45] Studies have examined associations between consumer knowledge, food labeling policies, and purchasing behavior.[46]

---

39 "National Standard for Organic and Bio-Dynamic Produce: Edition 3.7," Department of Agriculture and Water Resources, Australian Government, last modified September 16, 2016, http://www.agriculture.gov.au/SiteCollectionDocuments/aqis/exporting/food/organic/national-standard-edition-3-7.pdf.

40 Ibid.

41 Ibid.

42 *New Oxford American Dictionary*, 3 ed., s.v. "humus."

43 "National Standard for Organic and Bio-Dynamic Produce," 13, 16.

44 "An act relating to establishing a regenerative soils program."

45 Renée Shaw Hughner, "Who Are Organic Food Consumers? A Compilation and Review of Why People Purchase Organic Food," *Journal of Consumer Affairs* 6 (2007): 94-110, accessed April 22, 2017, http://onlinelibrary.wiley.com/doi/10.1002/cb.210/abstract; Klaus G. Grunert, Sophie Hieke, and Josephine Wills, "Sustainability Labels on Food Products: Consumer Motivation, Understanding and Use," *Food Policy* 44 (2014): 177–189, accessed April 22, 2017, http://www.sciencedirect.com/science/article/pii/S0306919213001796; Melissa Vecchione, Charles Feldman, and Shahla Wunderlich, "Consumer Knowledge and Attitudes About Genetically Modified Food Products and Labelling Policy," *International Journal of Food Sciences and Nutrition* 66 (2015): 329-335, https://www.ncbi.nlm.nih.gov/pubmed/25519248; Joanna K. Sax and Neal Doran, "Food Labeling and Consumer Associations with Health, Safety, and Environment," *Journal of Law, Medicine, and Ethics* 44 (2016): 630-638, accessed April 22, 2017, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2787163.

46 Ibid.

The size of the organic foods market has grown substantially in recent decades, with sales increasing from $7.8 billion in 2000 to an estimated $35 billion in 2014.[47] A 2007 literature review identified the dominant trends in market research on products labeled as organic.[48] While perceived health and environmental benefits attracted consumers, high prices and confusion with certification labels deterred them.[49] In a highlighted 2004 study from several European countries, consumers expressed significant difficulty with interpreting "organic" labels and differentiating between the appearance of organic and nonorganic products. Research from the past five years, however, has observed increasing levels of familiarity with organic and other environmentally-focused food labels.[50] This increase in consumer awareness parallels the increase in the size of the organic foods market.

Studies of a specific environmentally-focused food label, the Carbon Trust Footprint designation, might better indicate the potential market for foods with a regenerative soil certification. As explained above, one of the principal environmental benefits of regenerative agriculture is its capacity to sequester carbon. Consumers attracted to products with the Carbon Trust label, which identifies items that are carbon neutral or minimize water consumption, may also be interested in products with regenerative soils certification.[51]

Though the body of market research on carbon labeling is limited, there is some evidence to suggest that consumer awareness of carbon footprint labeling is high and that consumers may be willing to pay a premium for products with lower carbon footprints, albeit these studies appear to be limited to countries other than the U.S. The U.K., for example, is unique in its history of carbon labeling, as the Carbon Trust label has existed there since 2009.[52] A 2012 British study found that consumers in the U.K. were about as familiar with the Carbon Trust Footprint label as they were with other prominent food labels, such as the "Fair Trade" and "Animal Welfare" labels.[53] Furthermore, the Carbon Trust label performed better than other labels when consumers were asked to correctly define the purposes of the different certifications.[54] Another 2012 study focused on Chile, which does not have an established history of carbon labeling. This study found that consumers were willing to pay a 10-29 percent price premium for products with lower carbon footprints.[55]

---

47 Carolyn Dimitri and Catherine Greene, "Recent Growth Patterns in the U.S. Organic Foods Market," *USDA Agricultural Information Bulletin* 77 (2002): 1; "Organic Market Overview," United States Department of Agriculture: Economic Research Service, last modified April 4, 2017, https://www.ers.usda.gov/topics/natural-resources-environment/organic-agriculture/organic-market-overview/.

48 Hughner, "Who Are Organic Food Consumers?" 94-110.

49 Ibid.

50 Grunert, Hieke, and Wills, "Sustainability Labels on Food Products"; Vecchione, Feldman, and Wunderlich, "Consumer Knowledge and Attitudes"; Sax and Doran, "Food Labeling and Consumer Associations."

51 "Carbon Trust Product Footprint Certification," Carbon Trust, accessed April 27, 2017, https://www.carbontrust.com/client-services/certification/product-footprint/.

52 "Carbon Trust Footprint Label," Carbon Trust, accessed May 1, 2017, https://www.carbontrust.com/media/558406/carbon-trust-product-footprint-certification.pdf.

53 Grunert, Hieke, and Wills, "Sustainability Labels on Food Products," 182.

54 Ibid., 184.

55 Rodrigo Echeverría et al., "Willingness to Pay for Carbon Footprint on Foods," *British Food Journal* 116 (2012): 192, accessed April 27, http://www.emeraldinsight.com/doi/pdfplus/10.1108/BFJ-07-2012-0292.

While these studies reflect positive consumer reactions to carbon certifications, carbon labeling faces many of the same challenges that other environmentally-focused food labels have encountered. A 2011 literature review on carbon labeling research observed that limited availability, confusion with label meaning, and lack of trust with the labeling process all negatively affect consumer awareness and willingness to pay.[56]

Conclusion

Other countries have recognized the benefits associated with regenerative agriculture and have chosen to implement related programs. While some of these programs have existed for several years, none have existed long enough for their impacts to be fully assessed. Moreover, because specific practices are not yet proposed in the Vermont bill, it is difficult to assess how those programs from abroad might inform policies in Vermont. The working group proposed in S.43 could further address the specifics of the implementation of regenerative agriculture practices. Specialty food labels have increased in popularity in recent years, particularly organic labels. Few studies have focused on carbon labeling, but as with other labels, time and increased awareness may result in heightened market potential. Market potential aside, regenerative agriculture is an effective carbon sequestration mechanism and may offer a sustainable and potentially economically viable path toward mitigating carbon emissions.

This report was completed on May 16, 2017, by David Brandt, Kaitlin Clark, Katja Ostojic, and Lauren Rayson under the supervision of Professors Eileen Burgin, Alec Ewald and Jack Gierzynski and with the assistance of Research Assistant Laura Felone in response to a request from Senators Chris Pearson and Brian Campion.

Contact: Professor Anthony Gierzynski, 517 Old Mill, The University of Vermont, Burlington, VT 05405, phone 802-656-7973, email agierzyn@uvm.edu.

56 Elin Röös and Heléne Tjärnemo, "Challenges of Carbon Labelling of Food Products: A Consumer Research Perspective," *British Food Journal* 113 (2011): 982-996.