Estimating Environmental Impacts of Climate Smart, Organic, and Regenerative Agriculture

Assessing Production Practices across Agricultural Paradigms

UNIQUE forestry and land use

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TABLE OF CONTENTS

1 INTRODUCTION

Global agriculture fulfils a number of vital human needs including food, fibre, and industrial inputs, along with providing livelihoods to millions of farmers. However, it also has a high environmental impact. Currently covering 40% of all global landmass, agriculture's share of global land use is projected to increase with the global population.[1] The negative effects of agriculture on the global environment include GHG emissions, biodiversity loss, soil and water degradation, water overuse, and deforestation. According to the most recent IPCC report on land, almost 12% of global GHG emissions (6.2 $GtCO_2eq$ yr) can be directly traced to agriculture. When other land use change (including deforestation related to agriculture) is factored in, the impact increases to 23%.[2,3] Land degradation threatens to release even higher amounts of carbon from the earth's soils.[4] According to the FAO, 33% of global soils have already been degraded, with negative effects including increased erosion, reduced water storage capacity, and declining soil fertility.[5] Biodiversity loss is another key impact that has been attributed to agriculture. This is caused by chemical pollution and the replacement of habitat with farmland. [6] Agriculture is also responsible for 70-90% of freshwater withdrawals from surface and groundwater and significantly affects water quality. [7] Given all of these environmental impacts, there has been an increasing call for the development of a more sustainable agriculture.

Three of the most commonly proposed approaches to reducing the environmental impacts of global agriculture are Climate-Smart Agriculture (CSA), Regenerative Agriculture (RA), and Organic Agriculture (OA). Each of these approaches aims to change the way the world farms, and each already exerts a significant influence on global agricultural practices. For example:

- The World Bank, a major proponent of CSA, is currently aiming through its *Next Generation Africa Climate Business Pla*n to encourage the adoption of CSA practices by 28 million African farmers by 2023.[8]
- In 2018, OA covered 1% of the world's total agricultural land, with an annual 2.9% increase in land cover. Organic crops accounted for 96.7 billion USD in retail sales in 2018.[9]
- Global RA network Regeneration International[10] currently engages with a network of more than 250 international partners and a growing number of Regeneration Alliances

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[1] IPBES (2019): Global assessment report on biodiversity and ecosystem services

[2] IPCC (2019). special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems

[3] Word Bank (2016). Future of Food: Shaping a Climate-Smart Global Food System

[4] Amelung et al (2020). Toward a global-scale soil climate mitigation strategy. Nat. Commun. 11, 5427

[5] FAO (2019) Recarbonization of Global Soils - A dynamic response to offset global emissions,

[6] IPBES (2019): Global assessment report on biodiversity and ecosystem services

[7] Foley, J. A. et al. (2005). Global consequences of land use. Science, 309(5734), 570–574.

[8] World Bank 2020: Next Generation Africa Climate Business Plan – Ramping Up Development Centered Climate Action. World Bank, Washington DC.

[9] Willer, H., Schlatter, B., Trávníček, J., Kemper, L., & Lernoud, J. (2020). IFOAM World of Organic Report (Rep.). Retrieved https://orgprints.org/37222/9/willer-et-al-2020-full-document-2020-02-28-4th-corrigenda.pdf

[10] https://regenerationinternational.org/about-us/

throughout the world, including in the U.S., South Africa, India, Canada, Belize, Mexico and Guatemala.[11]

Essentially, while CSA aims to do "more with less" (creating increased economic value while reducing pollution and using fewer natural resources), and organic aims to "do less harm" (to the environment), the goal of RA is to "do more good" for the planet.

This discussion paper offers a close comparative look at these three agricultural paradigms. After defining each approach, it examines the potential impacts that increased adoption of CSA, OA, or RA would be likely to have on the major environmental issues described above. Research comparing these agricultural paradigms remains largely absent in the literature. This paper is a contribution towards developing a nuanced comparative understanding of the primary contemporary approaches to decreasing the environmental impact of global agriculture.

While this paper reveals some key differences between the highlighted approaches (particularly regarding variation between specific practices and their associated environmental impacts), it also showcases many commonalities between the three.

[11] Contrary to common perception, it is not only practiced in the US and EU. In Kenya the Regenerative Agriculture initiative supporting 10,000 farmers is funded by the IKEA Foundation through the Alliance for a Green Revolution in Africa.

2 DEFINITIONS

This chapter presents general definitions for conventional agriculture (CA), CSA, OA and RA. Detailed descriptions of specific production practices and technologies can be found in chapter 3.

'Conventional' agriculture

In general, this term refers to production systems that use all available technology (within the limits of legal regulation) to maximize profitability. According to the Oxford Dictionary of Environment and Conservation, conventional agriculture refers to "farming practices that involve the use of chemical fertilizers, pesticides, and machinery"[12]. Other practices including crop rotation and organic soil amendments are also often utilized. However, this concept has no clear technical meaning and is typically only defined in opposition to various 'alternative' approaches to agriculture.

Differences exist within the characteristics of conventional agriculture in the developed and developing world. Conventional production in some nations has become very industrialized to maximize profits. The green revolution in Asia (improved seeds and more fertilizer (probably mostly synthetic)) improved food security in Asia. In Africa, many conventional farmers are "organic" by the fact that they don't have access to improved inputs.

Climate Smart Agriculture

CSA was conceived by FAO and World Bank during the 2010 Hague Conference on Agriculture, Food Security, and Climate Change. According to the FAO:

"Climate-smart agriculture (CSA) is an approach for developing actions needed to transform and reorient agricultural systems to effectively support sustainable development and ensure food security under climate change."[13]

The World Bank defines it in the following way: "Climate-smart agriculture (CSA) is an integrated approach to managing landscapes—cropland, livestock, forests and fisheries--that address the interlinked challenges of food security and climate change."[14]

In more detail, CSA refers to practices that move toward the following goals:

1. *Sustainably increasing agricultural productivity to support equitable increases in incomes, food security and development*
2. *Adapting and building resilience to climate change from the farm to national levels*
3. *Developing opportunities to reduce GHG emissions from agriculture compared with past trends.*

It is important to note, however, that these goals are aspirational and all three are not always adequately reflected in CSA implementation projects. In addition, CSA is more than just a set of practices – it is also a framework for policymakers and climate finance funders aimed at directly

[12] Park, C. (Ed.). (2012). Conventional Agriculture. In Dictionary of Environment and Conservation. Oxford. Pg 85.
[13] FAO. (2013). Climate Smart Agriculture Sourcebook (2nd ed.). Rome
[14] World Bank (2020) Climate Smart Agriculture.

linking agriculture and climate indicators. As elaborated in the FAO CSA Sourcebook, "CSA is an approach to developing the technical, policy, and investment conditions to achieve sustainable agricultural development for food security under climate change". [15]

As the above definitions show, a key element of CSA is its focus on balancing environmental protection with food security needs. Global development and poverty reduction are thus seen as integral goals of CSA, setting this approach apart from other sustainable agriculture paradigms.

Organic agriculture

Organic agriculture is an approach and set of farming practices that originated in the 1940s in response to concerns about soil degradation in agricultural systems. While starting out primarily as an informal social movement in Europe, Japan and the United States, by the 1990s organic had been formalized as a production system with national and internationally recognized certification standards. Certification and market demand have made it so organic producers typically receive a price premium for their products,

The International Federation of Organic Movements (IFOAM) has formulated a broad definition of organic that is accepted by its subsidiary member organizations: *"Organic Agriculture is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved."*[16]

A more technical definition can be found in the USDA's organic certification guidelines. According to these, "*produce can be called organic if it's certified to have grown on soil that had no prohibited substances applied for three years prior to harvest. Prohibited substances include most synthetic fertilizers and pesticides." GMOs are also prohibited. Livestock must meet stricter animal welfare standards, be fed 100% organic feed, must spend a certain amount of time on pasture, and cannot receive antibiotics.*[17] [18]

This definition is very closely aligned with the EU organic standard, as demonstrated by the current organic equivalency agreement between the US and the EU. This agreement states that the two organic certification systems are legally interchangeable (despite some small differences). These differences are outlined in the table below.

Table 1 Comparison of international organic standards

	USDA Organic Standard	EU Organic Standard[19]	Global South
Certification and inspection Systems	• nationally based, more detailed guidance for certifiers	• internationally accredited (as EU-wide regulation), certifiers	• generally oriented toward export markets, often industrial in scale

[15] FAO. (2013). Climate Smart Agriculture Sourcebook (2nd ed.). Rome
[16] IFOAM General Assembly (2008). Definition of Organic Agriculture.
[17] McEvoy, M. (2019). Organic 101: What the USDA Organic Label Means.
[18] National Organic Program, § Title 7, Chapter 1, Subchapter M, Par 205 (United States Federal Government 2020).
[19] Kosovska, M. (2013). Equivalence of organic food standards in the European Union and the United States of America

	-certifiers regularly audited by USDA • greater transparency/ harmonization in organic regulations	regulated at member state level (but typically fairly independent) • multiple member states not always harmonized	• certification often cost-prohibitive
Crop Regulations	• non organic and organic crops can be grown on same production unit • antibiotic spray allowed for apples and pears (not included in equivalency agreement	• non organic and organic crops cannot be grown on same production unit	• producers are required to maintain or improve the fertility and biological activity of the soil [20]
Livestock Regulations	• antibiotics use not allowed under any circumstances • less strict enforcement of animal welfare rules	• only sick animals can receive antibiotics (no preventative use) • animal welfare standards somewhat stricter • slightly higher percentage of omnivore feed can be conventional	

Source: *Organic Agriculture and the Law* FAO 2012

Common to all organic standards is the fact that farmers often grow a single crop, plant, or livestock species, variety, or breed in a field or farming system at a time for efficiency reasons (monoculture). They also often use mechanical tillage.

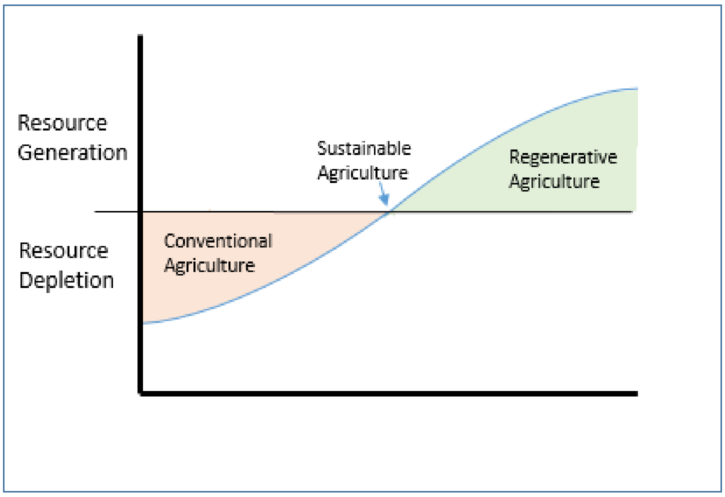
Despite the technical nature of certified organic agriculture, it still retains some elements of its origins as a social movement, leading to frequent internal tensions. For example many small-scale organic farmers express distrust of corporate and governmental actors, citing perceived efforts to weaken certification standards. These tensions are often reflected in fierce political disputes over definitions and the details of organic regulations.[21]

Regenerative agriculture

RA is a new movement in the agricultural sector hailed as a potential solution to catastrophic climate change effects. The 'regenerative' concept has gained popularity in a variety of fields[22]. In essence, regeneration calls for a movement beyond goals of sustainability toward a new aim of regenerating and restoring the natural environment.

[20] Morgera et al (2012). Organic Agriculture and the Law. FAO Legislative Study 107.
[21] Fouilleux & Loconto (2016). Voluntary standards, certification, and accreditation in the global organic agriculture field: A tripartite model of techno-politics. Agriculture and Human Values, 34(1), 1-14.
[22] Mang & Reed (2012)

Figure 1. Regenerative concept applied to agriculture. Adopted from Mang & Reed 2012.



Aligned with a 'beyond sustainability' paradigm, RA can be broadly defined as agriculture that has a net positive environmental impact, particularly in terms of soil carbon sequestration and soil biodiversity. According to Regeneration International, *"Regenerative Agriculture describes farming and grazing practices that, among other benefits, reverse climate change by rebuilding soil organic matter and restoring degraded soil biodiversity – resulting in both carbon drawdown and improving the water cycle"*.[23] As a new movement, RA includes a wide variety of ideas and approaches to agriculture. Actors ranging from conventional grain farmers to organic growers to permaculture practitioners have claimed the RA mantle. As such, efforts to create a verifiable international standard for RA have been limited.

While organic processes are not necessarily required for RA, what is currently the most advanced RA certification scheme has emerged from the organic sector. In 2017 an organization of farmers in the US developed a new RA certification called ROC (Regenerative Organic Certified) as an add-on to existing organic certification systems in an effort to promote RA practices. This new certification system is aiming to expand into Europe and the rest of the world. As a certification system, ROC provides a more technical definition than that provided by RI. This definition forms the basis of their three tiered certification system, and states that RA should:

- *"Increase soil organic matter over time and sequester carbon below and above ground, which could be a tool to mitigate climate change;*
- *Improve animal welfare*
- *Provide economic stability and fairness for farmers, ranchers, and workers".* [24]

The regenerative agriculture movement received a big push from the international initiative "4 per 1000"[25], launched by France on 1 December 2015 at the COP 21. The aim of the initiative is to demonstrate that agriculture, and in particular agricultural soils can play a crucial role where food security and climate change are concerned.

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[23] Regeneration International (2020). Why Regenerative Agriculture?
[24] Regenerative Organic Certified. (2020). Framework for Regenerative Organic Certified.
[25] 4 Per 1000 Initiative (2020)

3 ENVIRONMENTAL IMPACTS OF CSA, OA, AND RA

The comparative analysis of CSA, OA and RA follows a stepwise approach.

Step 1 Representation

As described above, it can be difficult to clearly define various approaches to sustainable agriculture. In order to reasonably compare the environmental performance of the three approaches to agriculture described above, we selected the following documents to represent each approach: the Climate Smart Sourcebook produced by FAO, the USDA Organic Standard and regulations, and the Certification Framework of the ROC. While the ROC standard cannot be considered representative of the full breadth of RA (particularly in that it is directly based on the USDA organic certification system), it is the most technically developed RA framework currently available and is thus used here.

Step 2 Characterization

Based on the three documents identified above, we generated a list of practices *prohibited*, *allowed*, *encouraged*, or *required* by each agricultural approach. While simplified, this information makes it possible to directly compare technical guidelines for each approach. However, it is important to note a few key differences. First, because CSA does not include a certification system, this approach has no required or prohibited practices. Second, because the ROC is an add-on certification directly based on the USDA organic standard, it can only be either the same as or more strict than this standard. Third, the ROC standard contains three sub-levels, each requiring an increasing number of practices. This analysis uses the least-strict Bronze level. Finally, it is important to note that only a very small portion of RA farms currently abide by the ROC standard. Information on farm practices in each system is presented in table 2.

Step 3 Scoring

The analysis divides environmental impacts into several key categories: Biodiversity, GHG emissions, soil health, water quantity and quality, as well as impacts on land use and land use change (LULUCF). Based on the available scientific evidence in the literature, we score practices that have been shown to have a positive effect on a given category with a '+', while those with a negative impact are scored with a '-'. Practices with mixed impact are marked with a +/-, and those for which insufficient data is available are left blank.

Step 4

In a last step, all scores are brought together with an equal weight, to show the overall environmental impact of each approach for each category and in total.

Table 2. Environmental impacts by practice and production system

Practice:	CSA	OA	RA	Biodiv.	GHG	Soil	Water	LULUC
No-till farming	Encouraged	Allowed	Required		+	+	+	+
Crop Rotations	Encouraged	Encouraged	Required		+	+		+
Year Round Vegetative cover	Encouraged	Encouraged	Encouraged		+	+	+	+
Rotational Grazing	Encouraged	Encouraged	Required		+	+	+	-
Soil less growing	Allowed	Allowed	Prohibited				+	+
Imported (off farm) fertilizers	Allowed	Allowed	Discouraged		+/-	+/-	-	+
Organic Fertilizer Use	Encouraged	Required	Required	+	+	+	+	+
GMO	Allowed	Prohibited	Prohibited					+
Synthetic Fertilizers	Allowed	Prohibited	Prohibited	-	-	+/-	-	+
Synthetic Pesticides	Allowed	Prohibited	Prohibited	-		-	-	+
Livestock Confinement	Allowed	Prohibited	Prohibited	-	-	-	-	+
Agroforestry	Encouraged	Encouraged	Encouraged	+	+	+	+	+/-
Mulching	Encouraged	Encouraged	Required		+	+	+	+
Building Soil Organic Matter	Encouraged	Encouraged	Required	+	+	+	+	+
Green Manures	Encouraged	Encouraged	Encouraged		+	+	+	+
Biochar	Encouraged	Allowed	Encouraged		+	+		+
Soil Health Testing	Optional	Optional	Required	+	+	+	+	+

+ = beneficial effect; **-** = negative effect, +/- = context-dependent

Table 2 summarizes the results of the scoring of a number of practices along the key criteria. Details are provided by the paragraphs below.

Biodiversity

Many of the practices in Table 2 have been shown to have a strong influence on on-farm biodiversity. For example, agroforestry practices,[26, 27], increasing soil organic matter[28], application of organic fertilizer,[29 30 31] have been shown to increase biodiversity. On the other hand, use of confinement livestock practices[32], synthetic fertilizers[33] and pesticides[34] can have a negative effect on biodiversity. While CSA, OA, and RA all encourage various practices that benefit biodiversity, organic agriculture systems have specifically been shown to benefit biodiversity outcomes when compared with other systems[35 36], largely because they do not include synthetic inputs. CSA allows the use of these inputs, despite encouraging some beneficial practices. Because practices specific to RA (no-till, soil organic matter) are positively correlated with biodiversity[37], RA is given the highest ranking.

GHG Emissions

The relative GHG emissions reduction potential of each of the three approaches is disputed in the literature, with proponents of each claiming superiority. Because land use change makes up a separate category in this paper, only direct emissions will be considered in this section.

In terms of practices, there is clear evidence that no-tillage[38], organic fertilizer use[39], mulching[40], green manures,[41] and crop rotations[48] all reduce emissions, either through increased soil carbon sequestration or through reductions in nitrate emissions.

Rotational grazing has also been linked to increased carbon sequestration[42 43]. While the emissions reductions potential of RA has been unrealistically inflated according to some critics[44 45],

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[26] De Beenhouwer et al. (2013).
[27] Torralba et al. (2016).
[28] IUCN 2018
[29] Bengtsson et al. (2005).
[30] Burgess et al (2019).
[31] Mueller et al. (2014)
[32] Kronberg & Ryschawy 2019
[33] Mozumber et al (2006)
[34] Geiger et al (2010)
[35] Lichtenberg et al (2017)
[36] Rahmann (2011)
[37] Sapkota, Tek & Mazzoncini, Marco & Bàrberi, Paolo & Antichi, Daniele & Silvestri, Nicola. (2012). https://www.researchgate.net/publication/257805435_Fifteen_years_of_no_till_increase_soil_organic_matter_microbial_biomass_and_arthropod_diversity_in_cover_crop-based_arable_cropping_systems
[38] Bai et al 2019
[39] Burgess et al 2019
[40] Rodale Institute (2020) Regenerative Agriculture and the Soil Carbon Solution
[41] UNEP 2019
[42] Sanderman et al (2015)
[43] Mulamba & Lal (2007)
[44] Garnett et al (2017)
[45] WRI (2020)

the fact that many beneficial practices are required for the ROC (and only encouraged in CSA) means that RA is scored higher for $C0_2$ emission reductions. Organic farming systems, on the other hand, have not been clearly shown to have a beneficial effect on CO_2 emissions (positive factors may be outweighed by increased mechanical weed control and reduced yields).[46]

Soil Health

In terms of soil health and erosion reduction, RA is clearly the strongest performing of the three systems highlighted here. Proven soil-improving strategies including increasing soil organic matter[47] [48], reduced tillage[49], mulching[38], rotational grazing[50] [51], and soil health testing are all required practices under the ROC certification. However, RA does discourage import of off-farm fertilizers, which limits the degree to which organic matter and nitrogen can be added to soils on a given plot of land. Synthetic fertilizers have also been shown to increase soil organic matter[52]. Because CSA and OA are very similar regarding practices relevant to soil health, they are ranked equally in Figure 2.

Water depletion and degradation

Several of the practices in Table 2 have been demonstrated to affect water quality. For example, livestock confinement[53], tillage[54], and application of synthetic fertilizers and pesticides all lead to increased runoff[55], with negative effects on water retention and water quality. On the other hand, rotational grazing has been shown to increase infiltration rates[56] and decrease surface runoff.[57] Green manures, vegetative cover, and mulching also reduce runoff and erosion, which negatively affect water quality and retention rates. As in many other categories, the stronger required practices present in the ROC framework make it so RA is the best performing system of the three presented here, with organic falling between RA and CSA.

Impacts on LULUC

Unlike the other impacts above, Land Use and Land Use Change is an indirect rather than a direct impact of agricultural production. However, since agriculture is land-based, LULUC is important in assessing the environmental impact of various approaches to agricultural production.

Two factors play a role:

1. Yield factor: Efforts to increase agricultural sustainability in one area (for example reduced inputs) can sometimes lead to reduced crop yields. In this case reduced yields in one area might lead to increased production in another location, thus leading to deforestation or other

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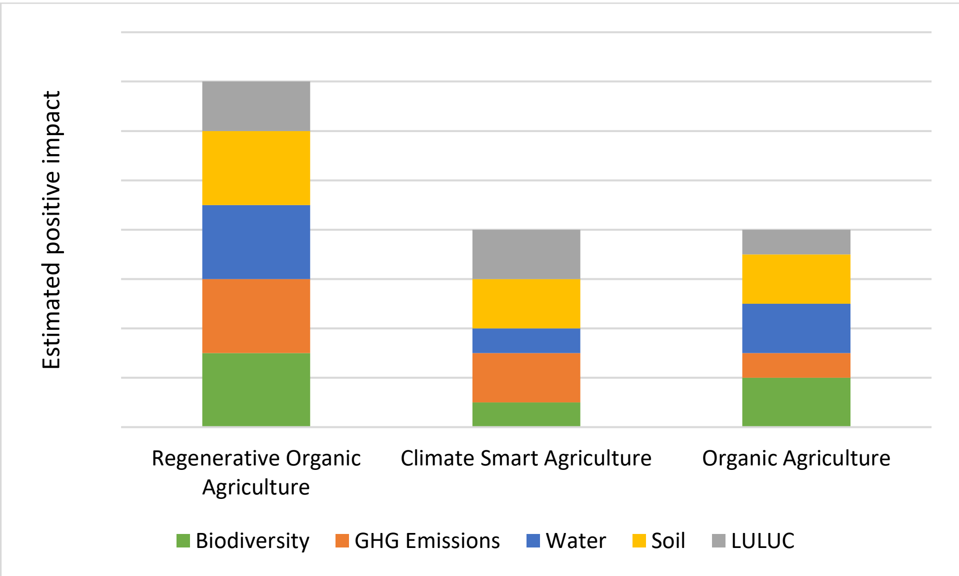
[46] Clark and Tilman (2017)
[47] Rodale Institute (2020) Regenerative Agriculture and the Soil Carbon Solution
[48] Amelung et al (2020)
[49] LaCanne CE, Lundgren JG (2018)
[50] Sanderman et al (2015)
[51] Teague et al (2011)
[52] Han et al (2016)
[53] Horak et al (2019)
[54] Reichuber et al (2019)
[55] Gonzalez (2018)
[56] Teague et al (2010)
[57] Park et al (2017)

land use change, with negative consequences for net GHG emissions[61]. CSA accepts various yield-increasing practices such as GMOS, synthetic inputs, and confinement livestock production. A body of research demonstrates lower yields (between 48 and 92%) in organic farming[62 63 64 65]. However, it is also important to note that high yields in conventional farming are associated with increased soil degradation over time[66]. Soil-less growing (not allowed in ROC farms) is another practice that might reduce the land use impacts of agriculture. Soil building practices in regenerative have been shown to increase yields[67].

2. Land factor: most organic producers and CSA farmers separate livestock and pastures from cropping systems, relying on off-farm purchases of feed for their animal herds, or fertility for their crop fields. This can externalize deforestation or other land use change for feed production elsewhere. Integrating crops and livestock on a multi-function operation as practiced under RA does not run this risk.

Figure 2 brings together the results for each impact category. The approaches were given 1 to 3 points per category based on the impacts of their practices listed in Table 2. 1 denotes lowest positive impact and 3 denotes highest positive impact. Farms certified by ROC are likely to perform best on many environmental indicators as well as in total.

Figure 2. Estimated cumulative positive environmental impacts of CSA, OA, and ROC by category



4 CONCLUSIONS

As shown above, differences in production practices between CSA, OA, and RA affect the environmental impact of each approach. Based on differences in the practices prohibited, allowed, encouraged, or required by each production approach, it is possible to rank each system in terms of its performance in various environmental indicators. Based on our results, farms certified by ROC as regenerative are likely to have the highest positive environmental impact.

In the future, key differences in governance and scale are likely to strongly influence environmental outcomes. For example, organic and ROC farms are held directly accountable by the need for inspection and certification. This makes it possible for specific practices to be required or prohibited. On the other hand, CSA takes a much softer approach, offering a framework and list of recommended practices, but no mechanism for accountability. Non-certified RA farms face similar loose guidelines. While 'soft' approaches can influence outcomes, certification systems can hold producers to a higher standard. Scale is also key – OA accounts for a much larger share of global agricultural land than ROC, for example, meaning that its influence on broader land use patterns is greater.

Despite these differences, it is also important to note that all three systems utilize the same general 'sustainable agriculture' practices. As a result, the approaches are highly compatible (in fact, a farm could easily utilize all three approaches at once). However, based on current trends, it is also clear that efforts to improve environmental outcomes will have to be accelerated rapidly to prevent irreversible degradation of the Earth's natural resources. If not, regeneration may become the only viable option.

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