The impact of market-based sustainability approaches on agrochemical and antibiotic use: a synthesis paper

July 2020

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Introduction

Why this topic?

Agrochemicals and antibiotics play a vital role in boosting land productivity and controlling pest and disease outbreaks in the agricultural, forestry, livestock, and aquaculture sectors. However, overuse of these substances negatively impacts human and environmental health. Global consumption of agrochemicals (defined in this report as fertilizers[1] and pesticides[2]) and antibiotics is increasing, mainly driven by high use in certain regions. For example, over the past 50 years, global use of nitrogen fertilizer surged from 12 million to 109 million tons per year, primarily driven by consumption in Asia.[3]

Ensuring that fertilizers are applied to farm soils at optimum levels is critical: overapplication can lead to severe water pollution while underapplication can impact soil quality and reduce farm productivity. While pesticide use has remained constant in some areas (e.g., United States) and decreased in many African countries, pesticide use has greatly increased in Asia and South America.[4] Reducing the use of pesticides through techniques such as integrated pest management (IPM) can lower the amount of toxic chemicals in soils and water.

Antibiotic use tends to be greatest in higher-income nations and those with higher levels of meat consumption, ranging from less than 25 milligrams of antibiotic per kg of meat in parts of Africa and Asia to over 250 milligrams per kg of meat in some European countries.[5] While antibiotics are critical for keeping infections from spreading in the livestock and aquaculture sectors, the use of antibiotics for non-therapeutic applications is increasing. Often, low levels of non-therapeutic antibiotics are added to food or water over long periods of time with the intention of preventing bacterial outbreaks and enhancing growth rates of fish, cattle, and other livestock.[6] Overuse and improper application of these drugs increases the resistance of bacteria to antibiotics, leading to the development of dangerously resilient strains of bacteria that cannot be controlled with pharmaceuticals.[7] When used in excess, antibiotics also accumulate in waterways and can negatively impact human and animal health downstream.[8] Currently, antibiotic use in the livestock sector accounts for an estimated 70-80% of global antibiotic consumption.[9]

To address these issues, many market-based sustainability approaches such as voluntary sustainability standards (VSS), sustainable sourcing codes, and public sustainability standards, include criteria for practices that control agrochemical use, promote soil health, and prohibit the use of non-therapeutic antibiotics. For example, many programs require that farmers conduct soil analyses to determine fertilizer needs, implement practices to identify and reduce erosion, maintain agrochemical-free buffer zones around water bodies, and use mulch or organic fertilizer to enhance soil health and reduce the need for synthetic fertilizers.[10] Likewise, many market-based sustainability approaches developed for the livestock and aquaculture sectors prohibit the use of non-therapeutic antibiotics and require that any antibiotics administered to animals have been prescribed by a veterinarian following a controlled treatment plan.[11] In addition, these programs promote sustainable sanitation and animal husbandry practices to maintain the health of fish, cattle, and other livestock with minimal antibiotic use.

Box 1. What do the United Nations' Sustainable Development Goals say about agrochemicals, soil health, and antibiotic use?

The practices promoted by market-based sustainability approaches to optimize agrochemical use, improve soil health, and reduce unnecessary antibiotic use reflect the United Nations' Sustainable Development Goals (SDGs), which are widely adopted by companies and nations around the globe as a framework for fostering sustainable development. For instance, SDG 6 ('Clean Water and Sanitation') seeks to improve water quality through reduced chemical pollution. SDG 12 ('Responsible Consumption and Production') promotes sustainable production practices including careful management of chemicals to minimize adverse environmental and human health impacts. With respect to soil health and erosion, SDG 15 ('Life on Land') aims to protect the environment by combating desertification and restoring degraded land and soil. As a result, the objectives of many market-based sustainability tools fit well with the SDGs, making it easy for supply chain actors who wish to align with both approaches.

Source: United Nations General Assembly (2015). Transforming our world: the 2030 Agenda for Sustainable Development, *A/Res/70/1*. Available at https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

Scope and approach of this synthesis

This synthesis investigates the impact of market-based sustainability approaches on agrochemicals, soil quality, and antibiotic use. Concerning agrochemicals and soil quality, we evaluate the impacts of programs on four outcomes in the agriculture, forestry, and livestock sectors: 1) fertilizer use; 2) pesticide use; 3) soil erosion; and 4) soil health. On antibiotics, we investigate the impact of market-based sustainability approaches on antibiotic use in the livestock and aquaculture sectors, as measured through any of the following four metrics: 1) amount of non-therapeutic antibiotics used; 2) frequency of use of non-therapeutic antibiotics; 3) accumulation of antibiotics in waterways; and 4) presence of antibiotic resistance. Higher or larger values of these metrics may indicate an overuse of antibiotics.

For both topics, two research questions were investigated:

- How much research has been conducted on the impact of market-based sustainability approaches on the outcomes of interest between 2009-2019, and how does the volume of research vary over time and by geographic region?
- How does participation in market-based sustainability approaches affect the outcomes of interest?

This study used a systematic review approach to investigate the above questions. Systematic reviews involve a structured framework to methodically and comprehensively search for relevant research, screen search results, and analyze their findings. The approach used in the review was designed to identify all relevant studies published from 2009-2019. All studies included in the review met detailed qualifying criteria related to research design, study population, the market-based sustainability approaches being assessed (the 'intervention'), and the outcomes investigated by the research. (See Annex A-C for details on this methodology and for a full list of the market-based sustainability approaches that were included in the review.)

Systematic review results and research trends

Agrochemical use and soil health in the agriculture, forestry, and livestock sectors

A total of 16 studies met the inclusion criteria for the systematic review that addressed agrochemical use and soil health. These studies contained 66 individual results, each of which addressed one of the four outcome areas. Fifteen studies addressed the agricultural sector and one investigated the forestry sector; no studies looked at the livestock sector. In addition to the studies that met the rigorous requirements to be included in the review, the search effort revealed 15 additional studies that met all except one of the inclusion criteria – most often the study design criterion. These additional studies are not analyzed here but have been included in the *Evidensia* library and are listed in the section entitled 'Papers Not Included in the Review but Added to the *Evidensia* Library.'

The volume of research was generally consistent over time and was low at one or two studies per year, except in 2018 when seven relevant studies were published. No studies were found between 2009-2011 or in 2014 (Fig. 1).

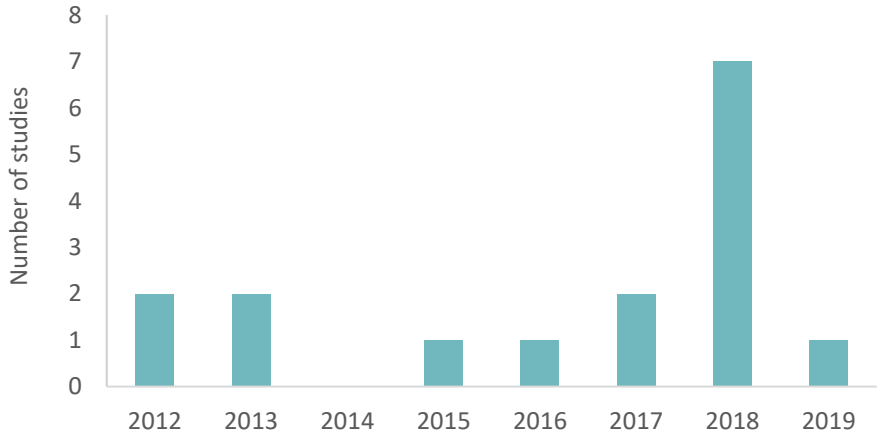

Figure 1. Trend in research volume over time. No studies meeting the inclusion criteria were published in 2009-2011 or 2014.

Most studies were conducted in Africa (six studies), followed by Asia (five studies), and South America (two studies). Central America and the Caribbean and Europe had one study each and none were found from North America (Fig. 2). Coffee was the most frequently investigated crop (five studies), followed by cocoa (four studies). Cotton and rice were each investigated by two studies; the forestry sector was the topic of a single study and one study conducted in China did not distinguish between agricultural products ('all products'; Fig. 2). The most frequently investigated market-based sustainability approaches were UTZ and the Rainforest Alliance with five studies each. Fairtrade had three studies and GlobalGAP and Better Cotton Initiative were the focus of two studies each. Four programs were investigated in one study each (4C Association, Forest Stewardship Council, Starbucks'

C.A.F.E. Practices, and the Green Food Program; these are denoted as 'other' in Fig. 2). Studies that looked exclusively at organic certification were not included in this analysis since the impact of organic certification on agrochemical use and soil health has been extensively reviewed elsewhere.[12]

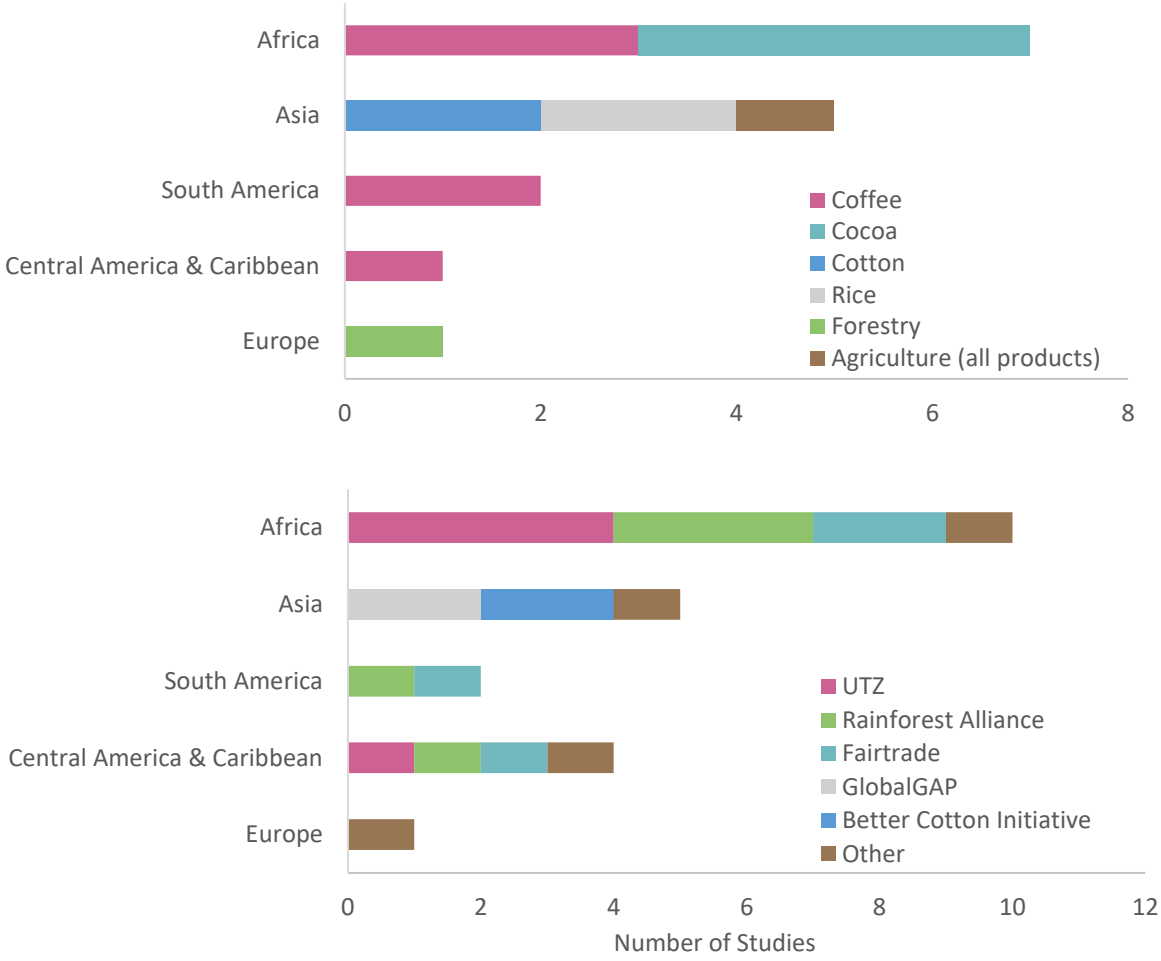

Figure 2. (TOP) Number of studies addressing each crop by geographic region (no studies were available from North America). (BOTTOM) Number of studies addressing each sustainability program by geographic region. 'Other' includes Forest Stewardship Council (Europe), Starbucks' C.A.F.E. Practices (Central America & Caribbean), Green Food Program (Asia), and 4C Association (Africa), which were all addressed in one study each. Two studies addressed more than one certification scheme: one investigated a multiple certification context (UTZ-Rainforest Alliance-4C) and the other looked at UTZ, Rainforest Alliance, Fairtrade, and C.A.F.E. Practices, but reported the impacts of these programs separately.

However, studies that examined organic certification in combination with another sustainability program covered by this review (e.g. dual Fairtrade-organic certification) were included.

Globally, pesticide and fertilizer use per unit land area are both highest in Asia and Europe; pesticide use is also high in South America.[13] However, the results of this review revealed that most research about the impact of market-based sustainability approaches on this topic has focused on Africa, which has one of the lowest agrochemical use intensities globally.[14] For example, in 2017, China used 13 kg of pesticides and 506 kg of fertilizer per hectare of cropland, compared to many African countries which used less than one kg of pesticides and under 100 kg of fertilizer per hectare.[15] Further, while Asia has been the focus of five studies related to agrochemical use, only one study has been conducted

in Europe. This finding points to a potential mismatch between agrochemical use hotspots and regions that have been prioritized for research.

Similarly, while global soil erosion risk is highest in North and Central America and parts of Asia, [16] this review only revealed erosion-related results from Europe, South America, and Africa. Both results for soil health were also from Africa, which is a key region for soil health research since, globally, it has some of lowest soil quality.[17]

Other key evidence hotspots and gaps are described below:

- Two outcome areas – fertilizer use and pesticide use – accounted for 83% of all results, whereas soil erosion and soil health accounted for 14% and 3%, respectively.
- Most of the results (58%) were from the coffee sector, followed by cocoa (14%), rice (12%), cotton (10%), all agriculture (3%), and forestry (3%). No results were found from the livestock sector.[18]
- Coffee was the only sector for which results were available from all four outcomes and was the only crop with research addressing soil health.
- No research was available for certain crops that are the subject of major market-based sustainability approaches, most notably tea, bananas, and palm oil.

Impacts of market-based sustainability approaches on agrochemical use and soil health

Study results most frequently addressed the outcome areas of fertilizer use (48% of results), followed by pesticide use (35%), soil erosion (14%), and soil health (3%); see Fig. 3. Overall, results were fairly evenly split between cases where the intervention performed better than the control (42% of results) and no differently than the control (47%).[19] In 11% of the results did participants in the sustainability program perform worse than the control group. Concerning fertilizer and pesticide use, results were relatively evenly split between the 'better' and 'no different' categories with very few results in the 'worse' category. Soil health had no 'worse' results (Fig. 4).

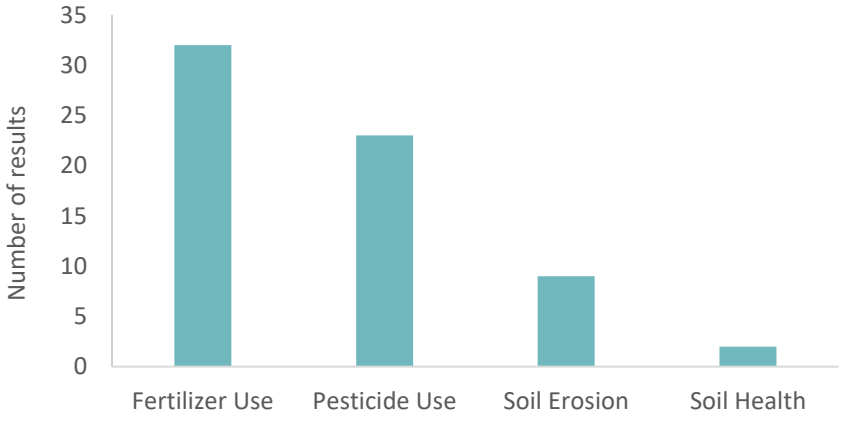

Figure 3. Number of results in each outcome area.

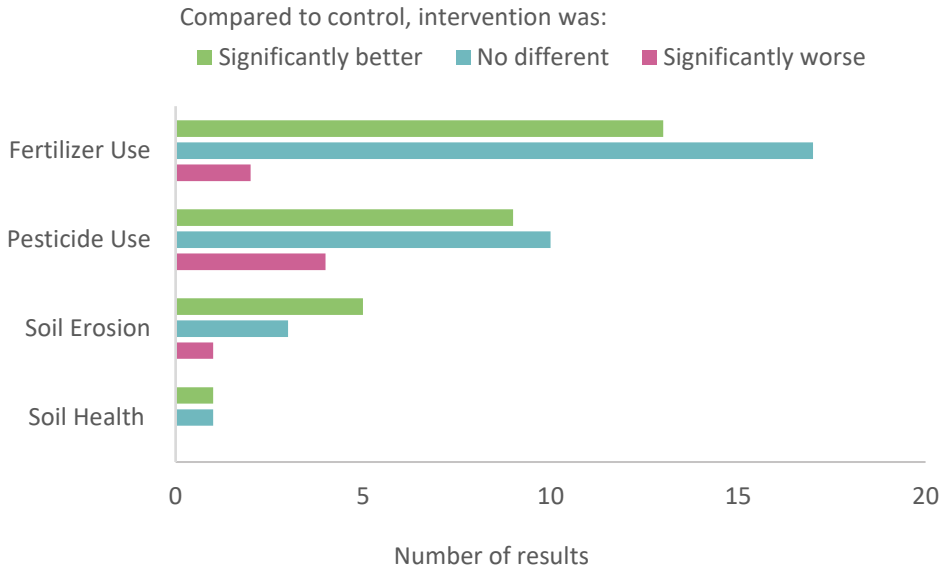

Figure 4. Number of results in each outcome area, showing the directionality of results. Statistical significance of results was based on the study authors' interpretation and usually assessed at a p-value of <0.05.

Fertilizer use

The metrics used to measure the impact of market-based sustainability approaches on fertilizer use included: the amount of synthetic and organic fertilizer used; the frequency of fertilizer application; accumulation of fertilizer in soil and water; and the use of soil tests to determine fertilizer needs. Because lower fertilizer use is not always better for crops and soils (e.g., if soil nutrients are depleted or if nutrient offtake from harvest exceeds replenishment rates), determination about whether producers applying the intervention performed better than the control group was made based on the study authors' interpretation.

Key findings

- Study authors generally framed higher use of synthetic fertilizers as environmentally detrimental and higher use of organic fertilizers (e.g., manure and compost) as beneficial. The use of soil tests to determine nutrient needs was also framed positively.
- Africa had the highest number of results concerning fertilizer use (15 results), followed by Asia (10) and South America (six). Only one result was available from Europe and no results were available from Central America and the Caribbean (Fig. 5).
- Fertilizer use was most frequently investigated in coffee (16 results) but this outcome was also studied in the cocoa, cotton, rice, and forestry sectors, and in one study that investigated 'all agriculture' (Fig. 5).
- In more than half of all results for this outcome (53%), the intervention group was not significantly different from the control group. In 40% of the results, participants performed better on fertilizer use than the control group while in 7% of the results they performed worse.

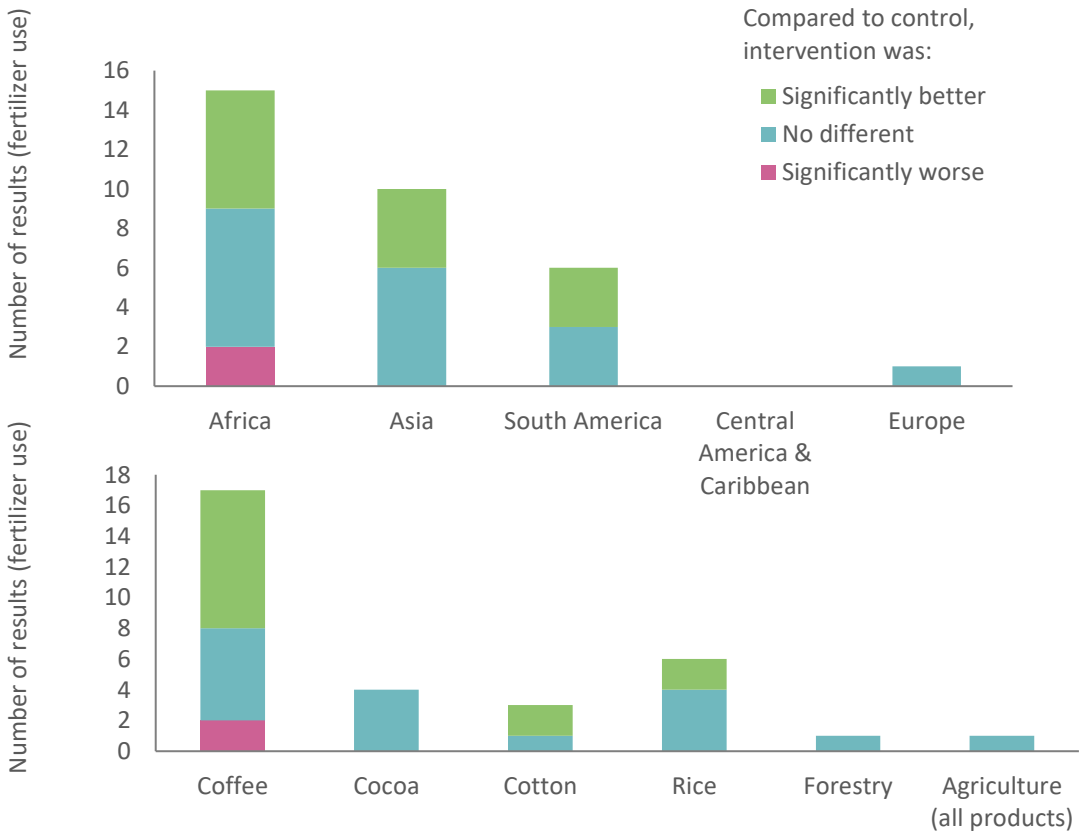

Figure 5. Number of results for the fertilizer use outcome by geographic region (TOP) and crop (BOTTOM) showing the distribution of 'better', 'no different', and 'worse' results.

Pesticide use

The effects of market-based sustainability approaches on pesticide use was measured through the following metrics: use of banned pesticides; amount of pesticide used; accumulation of pesticides in non-application zones (soil and water); measures to minimize spray drift; frequency of pesticide application; use of integrated pest management practices (IPM); and implementation of spill prevention and proper storage measures. This review only considered the impact of pesticide use on environmental health and does not include metrics related to human health. Similar to the fertilizer use outcome, the directionality of these metrics was determined based on the study authors' interpretation.

Key findings

- Overall, researchers framed higher use of pesticides including herbicides and fungicides as negative whereas IPM practices such as cultural weed control[20] were framed positively.
- Results for pesticide use were available from Africa, Asia, and South America. No studies from Central America and the Caribbean or Europe addressed this outcome (Fig. 6).
- The majority of results for this outcome came from the coffee sector (56% of all results) and the remaining results were distributed between cocoa, cotton, rice, and 'all agriculture' (Fig. 6).
- Results were fairly evenly split between 'better' and 'no different' results (39% and 43% of results, respectively). In four results (17%), the intervention performed worse than the control.

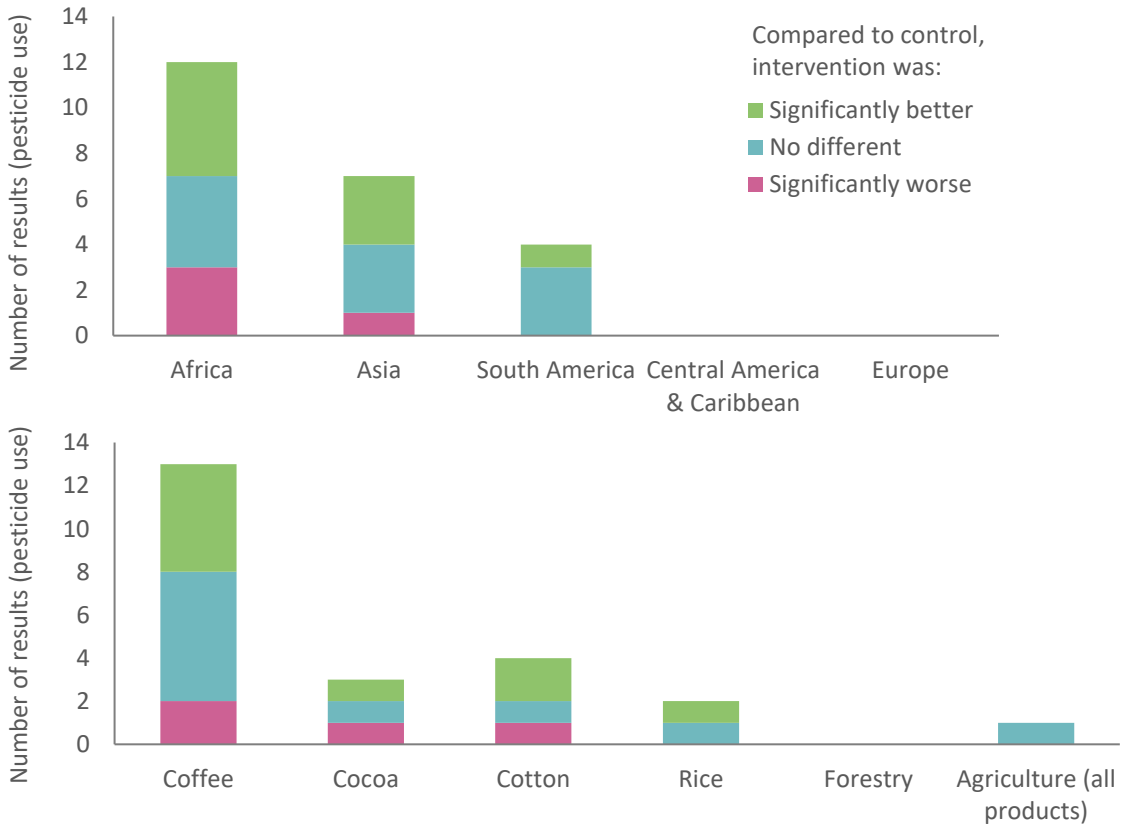

Figure 6. Number of results for the pesticide use outcome area by geographic region (TOP) and crop (BOTTOM) showing the distribution of 'better', 'no different', and 'worse' results.

Soil erosion

Soil erosion is often exacerbated by agricultural activities and is undesirable because it causes the loss of topsoil, which is high in organic matter, nutrients, and soil biodiversity. Erosion can also cause sediment to be deposited into waterways, which degrades water quality and disrupts hydrological processes.[21] Steep slopes and bare areas are most prone to erosion. The impact of market-based sustainability approaches on soil erosion was measured through the following metrics: presence of groundcover; presence of erosion-control measures on steep slopes; sedimentation in waterways; and loss of topsoil.

Key findings

- Overall, there were few results related to soil erosion, including three results from Africa, five from South America, and one from Europe (Fig. 7).
- In more than half of the results, producers applying the intervention performed better than the control group. Three results found a neutral impact and one result revealed a negative impact.
- Results for this outcome were only available for the coffee, cocoa, and forestry sectors (Fig. 7).

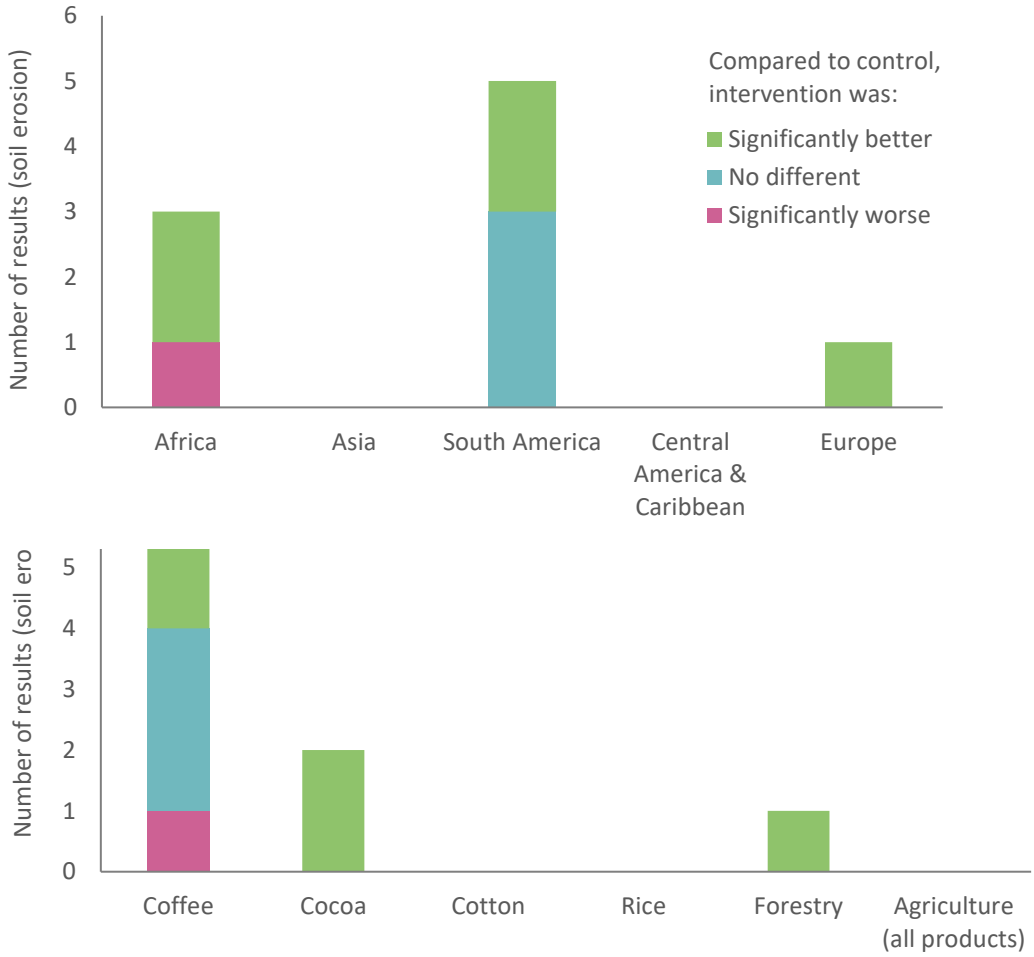

Figure 7. Number of results for the soil erosion outcome area by geographic region (TOP) and crop (BOTTOM) showing the distribution of 'better', 'no different', and 'worse' results.

Soil health

Soil health can be measured through its organic content, physical structure, biological diversity, and chemical composition.[22] Because the indicators of soil quality are varied, this review included diverse metrics for measuring the impact of market-based sustainability approaches on soil health: soil organic matter; cation exchange capacity; macro- and micronutrient content; bulk density; infiltration rate; carbon and nitrogen mineralization; microbial and enzyme activity and biomass; and soil insect biodiversity.

Key findings

- Only two results that addressed the impact of market-based sustainability approaches on soil health were available. These two results were from a single study that investigated the impact of multiple certification (Fairtrade-Organic and Rainforest Alliance-UTZ-4C) on soil organic carbon content.
- Both results pertained to impacts in the coffee sector in Africa. One of these indicated a positive impact of the intervention on soil health and the other revealed a neutral impact (Fig. 8).

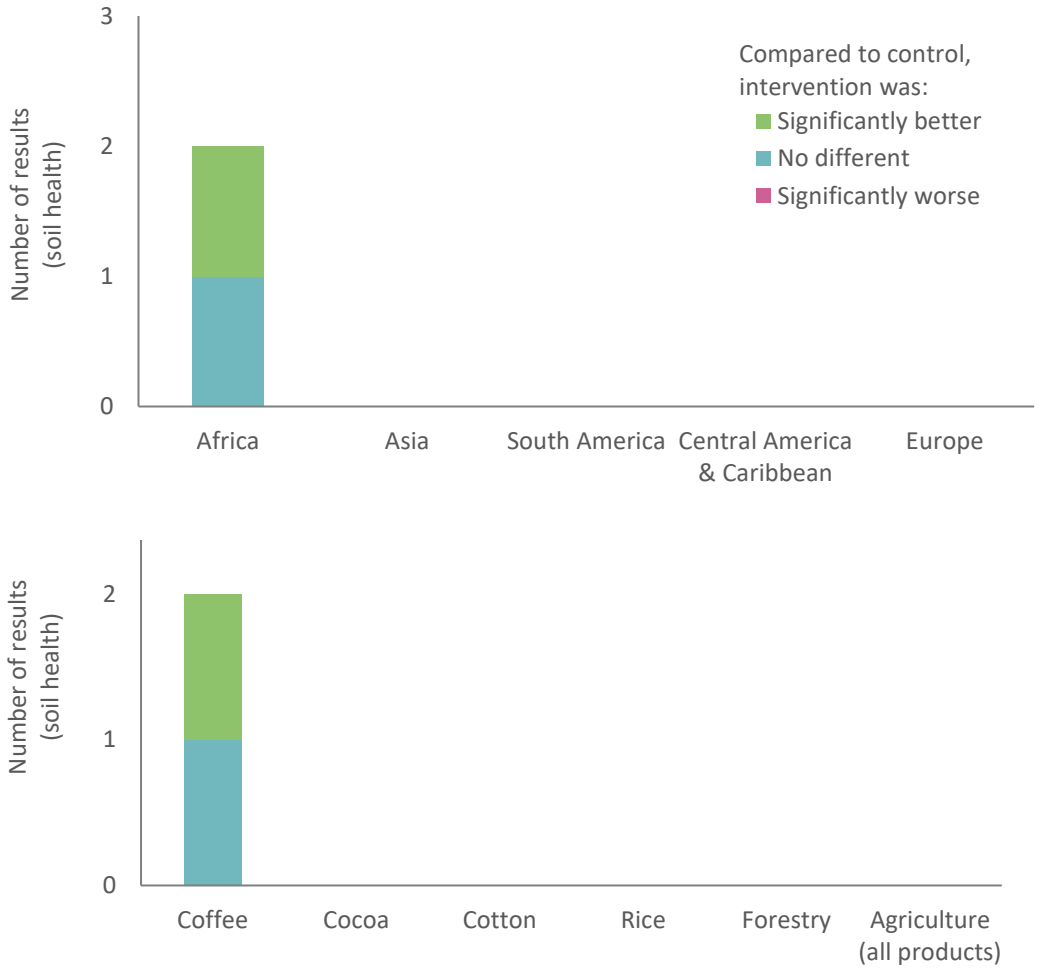

Figure 8. Number of results for the soil health outcome area by geographic region (TOP) and crop (BOTTOM) showing the distribution of 'better', 'no different', and 'worse' results.

Antibiotic use in the livestock and aquaculture sectors

The systematic search effort for the antibiotics component of this synthesis returned 6,129 relevant papers that were screened at the title level (i.e., the titles were read to determine their relevance to the review). From these, 1,401 papers were screened at the abstract level, and 105 of these papers were screened at the full text level. Based on the full text screening, no papers were found that met all the qualifying criteria to be included in this review.

- Just under 50% of the papers screened at the full text level met the outcome requirement (i.e., they investigated one of the four metrics used to measure antibiotic use). However, none of these papers addressed a relevant supply chain sustainability program.
- The remaining papers did not meet either the outcome, intervention, comparison (i.e., study design), or population (i.e., livestock or aquaculture sector) requirements. Many papers met only one of these requirements at most.
- Four of the 105 papers screened at the full text level addressed relevant market-based sustainability approaches (GlobalGAP, Good Aquaculture Practices, Aquaculture Stewardship Council (ASC), and one paper addressed GlobalGAP, Best Aquaculture Practices, and ASC), although none of these papers met the study design or outcome requirements.[23]
- Organic certification was not included in this analysis since the impact of organic certification on antibiotic use in the livestock sector has been extensively reviewed elsewhere,[24] and the organic aquaculture sector is not well developed.[25]

Discussion

Overall, the results of these two systematic reviews revealed that much more research has been conducted on the impact of market-based sustainability approaches on agrochemicals and soil health than on antibiotic use. The research shows that impacts on outcomes related to agrochemicals, soil erosion, and soil health are generally either positive or neutral. There were no studies on the effects of market-based sustainability approaches on antibiotic use and impacts that met the criteria for inclusion in the systematic review. This indicates a substantial research gap.

Certain parameters of the systematic review methodology may partially explain the lack of results on antibiotic use meeting the criteria for inclusion in the review. For example, the systematic review criteria included studies looking at the presence of antibiotic-resistant bacteria in livestock and aquaculture operations, but not those evaluating bacteria or antibiotic residues in meat, dairy, or other products. The latter constitutes a large body of research more associated with routine food safety testing and was therefore not included in this review. Also, the search strings did not include the names of specific bacteria species or antibiotics that may be associated with antibiotic overuse.

Notwithstanding these methodological considerations, the findings of the antibiotic use review suggest that there are substantial research gaps on this topic. For example, many widely adopted market-based sustainability approaches such as the Aquaculture Stewardship Council, Best Aquaculture Practices, and American Grassfed Association did not appear in any studies that met the inclusion criteria for this review, despite the fact that all three of these standards contain provisions that address antibiotic use.[26]

For agrochemicals, results from two of the outcome areas – fertilizer use and pesticide use – were relatively evenly split between cases where the intervention performed better than the control and those where it was no different, with a slightly higher proportion in the 'no different' category, and very few cases where the intervention performed worse than the control. Soil erosion was the only outcome area where the intervention performed better than the control in most of the results, and soil health was the only area with no 'worse' results. These finding are in line with previous *Evidensia* reviews that show a similar mix of positive effects and no significant effects across the full body of research addressing productivity and livelihoods[27] and conservation impacts.[28] Further, the distribution of 'better', 'no different', and 'worse' impacts is fairly consistent across the four outcome areas examined here, suggesting that sustainability programs do not have widely different levels of effectiveness across the multiple dimensions of agrochemical use and soil health. The discussion below draws from a range of papers included in the systematic review as well as other relevant research to investigate these findings.

Overall, the findings from the agrochemicals and soil quality portion of the review revealed a dearth of results on soil erosion and soil health, even though these topics are often addressed by market-based sustainability approaches.[29] One explanation may be that these outcome areas are often more difficult to measure than agrochemical use and may be overlooked by researchers as indicators of sustainability program impact. In addition, the impact of programs on soil-related metrics may take years to become apparent, which may partially explain the presence of 'no different' results for this outcome area. For example, in a study of FSC certified forests in Portugal, erosion-control benefits only began to appear in certified forest stands after at least five years of certification.[30] Another possibility is that the benefits of soil-related outcomes are not as immediately clear to farmers compared to agrochemical outcomes, causing them to underemphasize soil health and erosion control

practices. For instance, one study of Fairtrade certified coffee in Rwanda showed that certified farmers did not prioritize planting erosion-controlling grass since they specialized in coffee-growing and viewed grass as an additional crop to tend to, while non-certified farmers planted both grass and coffee.[31]

Four studies examined for this review illustrate the complex relationship between productivity and agrochemical use. In two studies, farms that implemented more sustainable practices related to agrochemicals and soil health had lower yields.[32] This finding may help explain the fact that producers who participate in market-based sustainability approaches do not always adopt practices that limit agrochemical use or boost soil health. However, in one of these studies, price premiums received by certified producers helped alleviate this tradeoff. Further, in two studies that assessed effects of the Better Cotton Initiative program, certified producers were able to increase their yields and revenues while adopting more sustainable integrated pest management (IPM) approaches.[33] In fact, certain IPM practices, such as manual weed control, had co-benefits as they reduced weed species while improving soil health.

In general, better access to training, education, and diagnostic tools related to good agricultural practices is important for increasing farmers' understanding and improving their capacity to implement more sustainable practices. Multiple studies show that training helps farmers effectively adopt practices such as IPM, soil fertility management, and other good agricultural practices.[34] In the studies examined for this review, one investigation into Rainforest Alliance Certified coffee in Colombia showed that certified farmers significantly increased their use of soil analyses to determine fertilization needs after becoming certified, leading to better soil nutrient management.[35] Further, this study found that the benefits of training extended beyond certified farms as producers shared their knowledge and experiences during monthly meetings with other certified and non-certified farmers alike. Importantly, studies also suggest that access to cooperative services and inputs may be necessary to help producers turn their knowledge into action. One study of UTZ Certified cocoa in Ghana demonstrated that farmers' knowledge of good agricultural practices was high, but implementation was limited by barriers such as the cost of adoption.[36]

More broadly, implementation of sustainable agrochemical and soil management can be hindered by counter-productive government policies and ineffective enforcement of program requirements. For example, a study of Fairtrade coffee in Rwanda found that the government coffee board in this region subsidizes fertilizers and pesticides and distributes these agrochemicals for free, encouraging their use.[37] Further, the cost for this program is built into the farm-gate price for coffee, meaning that certified farmers pay for this service even if they do not use it. In two other studies, lack of enforcement of program requirements resulted in poor implementation of sustainable practices related to agrochemicals.[38] These findings suggest that closer monitoring or improved assurance of program compliance and efforts to align market-based sustainability approaches with local policy could help drive improvements in agrochemical use and soil health.

Evidence gaps

The majority of results in the agrochemicals and soil health review – almost 60 percent – addressed impacts in the coffee sector, and the remaining results were distributed across cocoa, rice, cotton, forestry, and other mixed agriculture. No results were available from certain sectors that are the focus of major market-based sustainability approaches, most notably bananas and tea, despite evidence that the outcome areas addressed here are very relevant to these crops. For instance, bananas are often grown with high amounts of agrochemical inputs to control pests and disease[39] while tea is

frequently grown on steeply sloping areas that are prone to erosion, sedimentation, and fertilizer loading in nearby waterways.[40] Further, no studies were found that investigate the impact of market-based sustainability approaches on antibiotic use in the livestock or aquaculture sectors. To fill critical knowledge gaps, future studies should target the regions and commodities where challenges related to agrochemical use, erosion, soil health, and antibiotic use are most prominent but where the evidence base is scant or nonexistent.

Recommendations

Although these findings show that market-based sustainability approaches positively impact agrochemical use and soil health practices in many cases, evidence gaps and implementation barriers persist. Future research should target geographic regions where evidence is sparse but where sustainability programs could have a large impact on agrochemical use, soil erosion, soil health, and antibiotic use. For example, additional studies on agrochemical use in Asia, erosion in North and Central America, and soil health in Africa will improve our understanding of the potential of market-based sustainability approaches to alleviate existing challenges in these regions. Research in commodities other than coffee, especially bananas and tea, should also be prioritized to build an evidence base in these important sectors.

This review found positive impacts of sustainability programs on agrochemical use, erosion, and soil health in about half of the cases examined, but the explanations offered in these studies highlight additional complexities. In particular, training, access to cooperative services, aligned government incentives, and enhanced enforcement are all necessary to ensure broad and effective adoption of sustainable agrochemical use and soil health practices in the agriculture and forestry sectors.

Finally, while the use of antibiotics in the livestock and aquaculture sectors is a critical issue with implications for environmental and human health, this review found no studies that assess the impact of market-based sustainability approaches on this outcome. Although the topic of antibiotic use has received widespread attention in recent literature,[41] a comprehensive, systematic search of the literature did not reveal any studies that used a rigorous, empirical approach to investigate the impact of sustainability programs on antibiotic use. This finding points to a key gap in the research and highlights the need for future studies on the effectiveness of market-based sustainability approaches in controlling antibiotic use and its secondary impacts such as resistance and environmental contamination.

Endnotes

[1] In this report, 'fertilizers' refer to any material of natural or synthetic origin that is applied to soil or crops to supply essential nutrients for plant growth. Common nutrient fertilizers include nitrogen (N), potassium (K), and phosphorus (P).

[2] In this report, 'pesticides' encompasses herbicides, insecticides, fungicides, rodenticides, and miticides.

[3] FAO 2019.

[4] FAO 2019.

[5] Ritchie 2017.

[6] National Research Council 1980.

[7] Witte 2000.

[8] He et al. 2016.

[9] Ritchie 2017.

[10] *e.g., see* Starbucks' C.A.F.E. Practices (https://www.scsglobalservices.com/files/program_documents/cafe_scr_genericv3.4_011516.pdf); Fairtrade (https://www.fairtradecertified.org/sites/default/files/filemanager/documents/APS/FTUSA_STD_APS_EN_1.1.0.pdf); Rainforest Alliance (https://www.rainforest-alliance.org/business/resource-item/rainforest-alliance-sustainable-agriculture-standard/); Global Roundtable for Sustainable Beef (https://grsbeef.org/resources/Pictures/2017%20Template%20Graphics/grsb_principles_and_criteria_for_global_sustainable_beef_2016_logo%20(6).pdf); Forestry Stewardship Council (https://us.fsc.org/preview.fsc-std-usa-v1-1-2018.a-719.pdf)

[11] *e.g., see*: American Grassfed Association (https://www.americangrassfed.org/about-us/our-standards/); Best Aquaculture Practices (https://bapcertification.org/Standards); Aquaculture Stewardship Council (https://www.asc-aqua.org/what-we-do/our-standards/farm-standards/); Food Alliance (http://foodalliance.org/operations/).

[12] Benthein et al. 2019; Smith et al. 2019; Seufert et al. 2017.

[13] FAO 2019.

[14] Annual average pesticide use per area of cropland (arable land plus land under permanent crops) between 2007-2017; FAO 2019.

[15] FAO 2019.

[16] Nutrient depletion and soil pollution are highest in Central and West Africa and Western Europe and lowest in most parts of Asia and South America; FAO n.d.

[17] Based on soil nutrient depletion and soil pollution; FAO n.d.

[18] Note that each study contained at least one result, with many studies containing multiple results.

[19] Throughout this report, 'better' indicates that the intervention group performed significantly better than the control group; 'no different' indicates that there was no statistically significant difference between the two; and 'worse' indicates that the intervention group performed significantly worse than the control group. Statistical significance was assessed at a p-value of < 0.05, unless otherwise specified by the study authors. For more information see Annex A.

[20] Cultural weed control refers to methods such as crop rotation, improving soil fertility, and avoiding overgrazing, that maintain field conditions to naturally inhibit weed growth.

[21] Ritter 2012.

[22] Friedman et al. 2001.

[23] *GlobalGAP*: Horchner & Pointon 2011; *Good Aquaculture Practices*: David et al. 2019; *Aquaculture Stewardship Council*: Luthman et al. 2019; *GlobalGAP-Best Aquaculture Practices-ASC*: Elevancini 2017.

[24] *See* Tang et al. 2017; Smith-Spangler et al. 2012; Young et al. 2009.

[25] Andrews 2016.

[26] American Grassfed Association (https://www.americangrassfed.org/about-us/our-standards/); Best Aquaculture Practices (https://bapcertification.org/Standards); Aquaculture Stewardship Council (https://www.asc-aqua.org/what-we-do/our-standards/farm-standards/)

[27] Evidensia 2019.

[28] Komives et al. 2018.

[29] *e.g., see* Starbucks' C.A.F.E. Practices (https://www.scsglobalservices.com/files/program_documents/cafe_scr_genericv3.4_011516.pdf); Fairtrade (https://www.fairtradecertified.org/sites/default/files/filemanager/documents/APS/FTUSA_STD_APS_EN_1.1.0.pdf); Rainforest Alliance (https://www.rainforest-alliance.org/business/resource-item/rainforest-alliance-sustainable-agriculture-standard/); Global Roundtable for Sustainable Beef (https://grsbeef.org/resources/Pictures/2017%20Template%20Graphics/grsb_principles_and_criteria_for_global_sustainable_beef_2016_logo%20(6).pdf); Forestry Stewardship Council (https://us.fsc.org/preview.fsc-std-usa-v1-1-2018.a-719.pdf)

[30] Dias et al. 2015.

[31] Elder et al. 2013.

[32] Vanderhaegen et al. 2018; Haggar et al. 2017.

[33] Zulfiquar et al. 2019; Zulfiqar et al. 2016.

[34] Ingram et al. 2017; Fenger et al. 2016; Deppeler et al. 2014.

[35] Rueda & Lambin 2013.

[36] Ingram et al. 2017.

[37] Elder et al. 2013.

[38] Nie et al. 2018; Stuart et al. 2018.

[39] Comte et al. 2018; Mendez et al. 2018.

[40] Willemen et al. 2019; Sahoo et al. 2016. Zhang et al. 2003.

[41] *e.g., Livestock*: Duan et al., 2019; Karikari et al., 2017; Selvam et al. 2016; *Aquaculture*: Ström et al. 2019; Hedberg et al. 2018; Liu et al. 2017.

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Annex A – Methodology

The methods used in this synthesis were developed in 2017 by a working group that included academic researchers and experts in voluntary sustainability standards (VSS) and have been applied in *Evidensia* reviews published in 2018[1] and 2019.[2] The application of those methods in the current synthesis was done by a team consisting of staff and consultants from the *Evidensia* founding partners.

Scope of the reviews

To be included in the reviews on agrochemicals/soil health and antibiotic use (and in the corresponding *Evidensia* visual summary and knowledge matrix), each paper (called a 'resource') had to meet a detailed set of inclusion criteria related to the population under study, the intervention being assessed, the comparison (study design), and the outcome:

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Population
The scope of the review included all forms of crop production, livestock raising, and forest product production in any location. The review did not include aquaculture.

Intervention
Annex C lists the market-based sustainability approaches included in the search process for this review. These programs included VSS such as Fairtrade, UTZ, and Rainforest Alliance; company sourcing codes such as Starbucks C.A.F.E. Practices and Nespresso AAA; public sustainability standards; commodity-specific bans or moratoria; and supply chain investment programs. Organic certification was not included in this analysis because the impact of organic certification on agrochemical use and soil quality has been extensively reviewed elsewhere.[3]

Comparison
Resources had to empirically compare the performance of producers implementing/using a market-based sustainability tool to a non-participating control group, with the treatment and control groups selected using a rigorous matching process. Resources were also included if they compared a treatment and control group at multiple points in time (pre- and post-intervention), if they used modeling techniques to compare treatment and control scenarios, or if they conducted randomized controlled trials.[4] Systematic reviews, routine monitoring reports, descriptive resources, and modeling studies that examine future scenarios were not included in this analysis.

Outcome
The examined outcome areas were fertilizer use, pesticide use, soil erosion, and soil health. Specific metrics included in each outcome area are as follows:

Outcome area	Metrics
Fertilizer Use	Amount of synthetic and organic fertilizer used
	Frequency of fertilizer application
	Fertilizer accumulation in soil and water
	Use of soil tests to determine fertilizer needs
Pesticide Use	Use of banned pesticides
	Amount of pesticides used
	Accumulation of pesticides in non-application zones (soil and water)
	Measures to minimize spray drift
	Frequency of pesticide application
	Implementation of spill prevention and proper storage methods
	Use of integrated pest management practices
Soil Erosion	Presence of groundcover
	Presence of erosion-control measures on steep slopes
	Sedimentation in waterways
	Loss of topsoil
Soil Health	Soil organic matter
	Cation exchange capacity
	Macro- and micronutrient content
	Bulk density
	Infiltration rate
	Carbon and nitrogen mineralization
	Microbial and enzyme activity, biomass, and soil insect biodiversity

Antibiotic use

Population

The scope of the study population included in the analysis consisted of any livestock or aquaculture farm in any geographic location. Agricultural farms and forestry practices were not included in the analysis.

Intervention

The list of eligible market-based sustainability approaches and tools is available in Annex C and included VSS such as the Aquaculture Stewardship Council and American Grassfed Association, supply chain investment programs such as the Sustainable Fisheries Partnership (SFP), and implementation norms for responsible supply chains such as the Global Roundtable for Sustainable Beef (GRSB). Organic certification was not included in this analysis since the impact of organic certification on antibiotic use in the livestock sector has been extensively reviewed elsewhere,[5] and the organic aquaculture sector is not well developed.

Comparison

Resources had to empirically compare the performance of farms implementing/using a market-based sustainability tool to a non-participating control group, with the treatment and control groups selected using a rigorous matching process. Resources were also included if they compared a treatment and control group at multiple points in time (pre- and post-intervention), if they used

modeling techniques to compare treatment and control scenarios, or if they conducted randomized controlled trials.[6] Systematic reviews, routine monitoring reports, descriptive resources, and modeling studies that examine future scenarios were not included in this analysis.

Outcome
The examined outcome area was antibiotic use, which was measured with the following metrics:

Outcome area	Metrics
Antibiotic use	Amount of non-therapeutic antibiotics used
	Frequency of use of non-therapeutic antibiotics
	Accumulation of antibiotics in waterways
	Presence of antibiotic resistance

Search strategy

To find relevant resources, search strings were developed through an iterative and collaborative process, designed to ensure that the final set of resources accurately represented the available research. These search strings are provided in Annex B and were used to systematically search CAB Abstracts and Web of Science for all resources published from 2009 to 2019. The search results were cross-checked against a list of 'golden papers' (papers that are known to meet all of the qualifying criteria) to ensure that the results were accurate and comprehensive. In addition, Google Scholar was systematically searched to find relevant gray literature. All search results were then screened for relevance first by reading the title and then by reading the abstract of papers that qualified at the title level. For resources that passed these screens, the full text was acquired and read in full to make a final determination of eligibility according to the above-stated criteria. A record of resources excluded at the full text level, including the reason for exclusion, was maintained.

Results extraction

Resources that met the inclusion criteria were coded in an Excel database. Resources sometimes contained more than one 'study': for example, if they examined outcomes in distinct regions or using different methods. If a resource included more than one 'study', each study was coded separately. A single study could contain results for multiple outcomes.

One of three team members coded each paper. For each result, the coder determined which of the target outcome areas was examined; which market-based sustainability tool was examined; which specific metric was used to measure the outcome; which statistical test was used (and the p-value, if provided); and the author's conclusion about the relationship between the intervention and the outcome. The determination about whether a result was statistically significant was based on the study author's conclusion; for the vast majority of cases this indicates a p-value of 0.05 or less. Coders also recorded contextual information such as location, crop, date of data collection, and other variables.

To assess and ensure the consistency of coding among the multiple coders, Kappa tests were conducted at both the title and abstract screening level. At the full text level, two or more team members periodically coded the same article to ensure consistency.

Endnotes

[1] Komives, K., Arton, A., Baker, E., Kennedy, E., Longo, C., Pfaff, A., Romero, C. and Newsom, D. (2018). Conservation impacts of voluntary sustainability standards: How has our understanding changed since the 2012 publication of 'Toward sustainability: The roles and limitations of certification'? Available at https://www.evidensia.eco/resources/181.

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[4] These study types correspond to the following Evidensia evidence typology categories: 'empirical study – matched control, data collected before and after intervention,' 'empirical study – matched control, data collected post-intervention,' 'empirical study – control not matched, data collected before and after intervention,' 'modeling study - two scenario comparison,' and 'empirical study – randomized control trial.'

[5] *e.g. see* Tang, K.L., Caffrey, N.P., Nóbrega, D.B., Cork, S.C., Ronksley, P.E., Barkema, H.W., Polachek, A.J., Ganshorn, H., Sharma, N., Kellner, J.D., and Ghali, W.A. (2017). Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: A systematic review and meta-analysis. *Lancet Planet Health,* 1(8): 2316-e327.; Smith-Spangler, C., Brandeau, M.L., Hunter, G.E., Bavinger, J.C., Pearson, M., Eschbach, P.J., Sundaram, V., Liu, H., Schirmer, P., Stave, C., Olkin, I., and Bravata, D.M. (2012). Are organic foods safer or healthier than conventional alternatives?: A systematic review. *Anals of Internal Medicine*, 157(5): 348-366.; Young, I., Rajić, A., Wilhelm, B.J., and Waddell, L. (2009). Comparison of the prevalence of bacterial enteropathogens, potentially zoonotic bacteria and bacterial resistance to antimicrobials in organic and conventional poultry, swine and beef production: A systematic review and meta-analysis. *Epidemiology & Infection*, 137(9): 1217-1232.

[6] These study types correspond to the following Evidensia evidence typology categories: 'empirical study – matched control, data collected before and after intervention,' 'empirical study – matched control, data collected post-intervention,' 'empirical study – control not matched, data collected before and after intervention,' 'modeling study - two scenario comparison,' and 'empirical study – randomized control trial.'

Annex B – Search strings for CABI, web of science, and google scholar

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CABI – Search conducted on 10/24/2019

1 = (“certification” OR “quality standards” OR “quality label?ing” OR “sustainability standards”) AND yr:[2009 TO 2019]

2 = ((private OR company OR companies OR “supply chain*” OR corpor* OR food OR commodity*) AND (collective OR group OR industry OR aspiration OR commitment OR pledge OR declarati* OR “sourcing standard*” OR code* OR “code* of conduct” OR policy OR ban OR moratori* OR “market exclusion” OR agreement OR sanction*)) AND yr:[2009 TO 2019]

3 = ((fair* OR ethic* OR alternative OR sustainab* OR responsib* OR specialty OR eco OR ecologic*) NEAR (certify* OR standard* OR label* OR seal* OR scheme* OR trad* OR market* OR “value chain*” OR commodity*)) AND yr:[2009 TO 2019]

4 = ("fair trade" OR fairtrade OR fair-trade OR transfair OR "fair for life" OR "Rainforest Alliance" OR "Sustainable Agriculture Network" OR "UTZ Certified" OR "UTZ" or "FSC" OR "Forest Stewardship Council" OR "Global Partnership for Good Agricultural Practice" OR "Global GAP" OR "GlobalGAP" OR "4C Association" OR "Nespresso AAA" OR "CAFÉ Practices" OR "C.A.F.E. Practices" OR "Better Cotton" OR "Cotton made in Africa" OR Bonsucro OR "Ethical Tea Partnership" OR Trustea OR "soil association" OR "bird friendly coffee" OR "Smithsonian Bird Friendly" OR "Sustainable Coffee Challenge" OR "International Cocoa Initiative" OR "Linking Environment and Farming" OR "Union for Ethical BioTrade" OR "UEBT" OR "Roundtable on Sustainable Palm Oil" OR "RSPO" or "Indonesia Sustainable Palm Oil Standard" OR "ISPO" OR "Malaysia Sustainable Palm Oil Standard" OR "MSPO" OR "Palm Oil Innovation Group" OR "POIG" OR "Fair Flowers Fair Plants" OR "ProTerra" OR "Brazil Cattle Agreement*" OR "Global Roundtable for Sustainable Beef" OR "GRSB" OR "Food and Ranch Certification Program" OR "American Grassfed" OR "Canadian Beef Roundtable" OR "Joint Solutions Project" OR "Sainsbury's Sourcing Code" OR "Climate Collaborative" OR "Consumer Goods Forum" OR "Ethical Trading Initiative" OR "Supply Chain Initiative" OR "IDH Sustainable Trade Initiative" OR "We Mean Business" OR "GCF Impact Platform" OR "Verra Landscape Standard" OR "IDH Verified Sourcing Areas" OR "UN Global Compact" OR "Accreditation Services International" OR "Aid by Trade" OR "Alliance for Water Stewardship" OR "Australian Forest Certification Scheme" OR "Audubon G.U.L.F. RFM Certification Program" OR "BSC production" OR "Cerflor Forest Certification Program" OR "Chilean Sustainable Forest Management Certification System" OR "EnVeritas" OR "Equitable Origin" OR "FairWild" OR "Field to Market" OR "Florimark" OR "FlorVerde" OR "Flower Label Program" OR "Food Alliance Certified" OR "GEO Foundation" OR "Global Infrastructure Basel" OR "International Sustainability and Carbon Certification" OR "LEAF Marque" OR "Living Forest Standards" OR "Local Food Plus" OR "Max Havelaar" OR "Potato Sustainability Initiative" OR "Program for Endorsement of Forest Certification" OR "Proterra" OR "Roundtable on Responsible Soy" OR "Roundtable on Sustainable Biomaterials" OR "SAI Platform" OR "SIP Certified" OR "Social Accountability Accreditation Services" OR "Sustainable Forestry Initiative" OR "Textile Exchange" OR "Amazon Soy Moratorium" OR "Ban on Uzbekistan Cotton" OR "Cocoa and Forests Initiative" OR "Collaboration for Forests and

Agriculture" OR "Singapore Alliance for Sustainable Palm Oil" OR "Joint Solutions Project" OR "Africa Palm Oil Initiative" OR "Colombia D-free palm oil pledge" OR "Global Coffee Platform" OR "African Palm Oil Initiative" OR "Unilever sustainable agriculture code" OR "Nike Code of Conduct" OR "Marks and Spencer Sourcing Code" OR "AgWater Challenge" OR "Partnership for Sustainable Textiles" OR "Sedex Information Exchange" OR "WWF Jurisdictional Risk Assessment" OR "Governors Climate and Forest Task Force" OR "Sistem Verificasi Legalitas Kayu" OR "International Organization for Standardization" OR "Global Reporting Initiative" OR "Cocoalife" OR "Novo Campo" OR "Global Coffee Platform" OR "International Cocoa Initiative" OR "Amsterdam Declaration") AND yr:[2009 TO 2019]

5 = OR/1-4

6 = (farm* OR agricultur* OR horticultur* OR livestock OR forest* OR cattle OR grower* OR ranch OR producer* OR smallholder* OR small-holder OR “small holder” OR cooperative* OR co-operative* OR syndicate* OR “agricultural sector” OR “agricultural trade” OR “floriculture” OR “crop production” OR “agricultural product*”) AND yr:[2009 TO 2019]

7 = (coffee OR cocoa OR tea OR infusion* OR “yerba mate” OR c$amomile OR sugar* OR fruit* OR vegetable* OR banana* OR pineapple* OR mango* OR coconut* OR apricot* OR nut* OR cashew* OR “shea butter” OR argan OR rice OR quinoa OR bean* OR chickpea* OR “red kidney” OR lentil* OR soy* OR herb* OR spice* OR “olive oil” OR olive* OR wine OR honey OR cotton OR flower* OR floriculture OR “palm oil” OR “oil palm” OR beef OR cattle OR dairy OR livestock OR animal OR poultry OR pork OR eggs OR “non timber forest product” OR “NTFP” OR ((crop* OR forest*) NEAR produc*)) AND yr:[2009 TO 2019]

8 = OR/6-7

9 = ((fertiliz* OR fertilis* OR pesticide* OR herbicide* OR *insecticide* OR input* OR compost OR amendment* OR “spray drift” OR “integrated pest management” OR “IPM” or “pest management” OR nitrogen OR phosphorus OR erosion OR groundcover OR “ground cover” OR “erosion control” OR “soil organic matter” OR “soil carbon” OR “cation exchange capacity” OR “soil quality” OR “bulk density” OR “infiltration rate” OR ((“carbon mineralization” OR “nitrogen mineralization” OR microb* OR enzym* OR arthropod* OR *invertebrate* OR biomass OR *divers* OR “carbon content” OR “carbon storage”) NEAR soil))) AND yr:[2009 TO 2019]

10 = 5 AND 8 AND 9

11 = (cc:aa000 OR cc:ff100 OR cc:hh000 OR cc:hh200 OR cc:hh300 OR cc:jj700 OR cc:jj900 OR cc:kk000 OR cc:pp400) AND yr:[2009 TO 2019]

12 = 10 AND 11

Web of Science – Search conducted on 11/05/2019

Search limited to the years 2009-2019

# 1
TS=("certification" OR "quality standards" OR "quality label?ing" OR "sustainability standards")

# 2
TS=((private OR company OR companies OR “supply chain*” OR corpor* OR food OR commodity* OR group OR collective OR industry) Near/5 (aspiration OR commitment OR pledge OR declarati* OR “sourcing standard*” OR code* OR “code* of conduct” OR policy OR ban OR moratori* OR “market exclusion” OR agreement OR sanction*))

# 3
TS=((fair* OR ethic* OR alternative OR sustainab* OR responsib* OR specialty OR eco OR ecologic OR ecological) NEAR/3 (certif* OR standard* OR label* OR seal* OR scheme* OR trad* OR market* OR "value chain*" OR commodit*))

# 4
TS=("fair trade" OR fairtrade OR fair-trade OR transfair OR "fair for life" OR "Rainforest Alliance" OR "Sustainable Agriculture Network" OR "UTZ Certified" OR "UTZ" or "FSC" OR "Forest Stewardship Council" OR "Global Partnership for Good Agricultural Practice" OR "Global GAP" OR "GlobalGAP" OR "4C Association" OR "Nespresso AAA" OR "CAFÉ Practices" OR "C.A.F.E. Practices" OR "Better Cotton" OR "Cotton made in Africa" OR Bonsucro OR "Ethical Tea Partnership" OR Trustea OR "soil association" OR "bird friendly coffee" OR "Smithsonian Bird Friendly" OR "Sustainable Coffee Challenge" OR "International Cocoa Initiative" OR "Linking Environment and Farming" OR "Union for Ethical BioTrade" OR "UEBT" OR "Roundtable on Sustainable Palm Oil" OR "RSPO" or "Indonesia Sustainable Palm Oil Standard" OR "ISPO" OR "Malaysia Sustainable Palm Oil Standard" OR "MSPO" OR "Palm Oil Innovation Group" OR "POIG" OR "Fair Flowers Fair Plants" OR "ProTerra" OR "Brazil Cattle Agreement*" OR "Global Roundtable for Sustainable Beef" OR "GRSB" OR "Food and Ranch Certification Program" OR "American Grassfed" OR "Canadian Beef Roundtable" OR "Joint Solutions Project" OR "Sainsbury's Sourcing Code" OR "Climate Collaborative" OR "Consumer Goods Forum" OR "Ethical Trading Initiative" OR "Supply Chain Initiative" OR "IDH Sustainable Trade Initiative" OR "We Mean Business" OR "GCF Impact Platform" OR "Verra Landscape Standard" OR "IDH Verified Sourcing Areas" OR "UN Global Compact" OR "Accreditation Services International" OR "Aid by Trade" OR "Alliance for Water Stewardship" OR "Australian Forest Certification Scheme" OR "Audubon G.U.L.F. RFM Certification Program" OR "BSC production" OR "Cerflor Forest Certification Program" OR "Chilean Sustainable Forest Management Certification System" OR "EnVeritas" OR "Equitable Origin" OR "FairWild" OR "Field to Market" OR "Florimark" OR "FlorVerde" OR "Flower Label Program" OR "Food Alliance Certified" OR "GEO Foundation" OR "Global Infrastructure Basel" OR "International Sustainability and Carbon Certification" OR "LEAF Marque" OR "Living Forest Standards" OR "Local Food Plus" OR "Max Havelaar" OR "Potato Sustainability Initiative" OR "Program for Endorsement of Forest Certification" OR "Proterra" OR "Roundtable on Responsible Soy" OR "Roundtable on Sustainable Biomaterials" OR "SAI Platform" OR "SIP Certified" OR "Social Accountability Accreditation Services" OR "Sustainable Forestry Initiative" OR "Textile Exchange" OR "Amazon Soy Moratorium" OR "Ban on Uzbekistan Cotton" OR "Cocoa and Forests Initiative" OR "Collaboration for Forests and Agriculture" OR "Singapore Alliance for Sustainable Palm Oil" OR "Joint Solutions Project" OR "Africa Palm Oil Initiative" OR "Colombia D-free palm oil pledge" OR "Global Coffee Platform" OR "African Palm Oil Initiative" OR "Unilever sustainable agriculture code" OR "Nike Code of Conduct" OR "Marks and Spencer Sourcing Code" OR "AgWater Challenge" OR "Partnership for Sustainable Textiles" OR "Sedex Information Exchange" OR "WWF Jurisdictional Risk Assessment" OR "Governors Climate and Forest Task Force" OR "Sistem Verificasi Legalitas Kayu" OR "International Organization for Standardization" OR "Global Reporting Initiative" OR "Cocoalife" OR "Novo Campo" OR "Global Coffee Platform" OR "International Cocoa Initiative" OR "Amsterdam Declaration")

5
#4 OR #3 OR #2 OR #1

# 6
TS=(farm* OR agricultur* OR horticultur* OR livestock OR forest* OR cattle OR grower* OR ranch OR producer* OR smallholder* OR small-holder OR “small holder” OR cooperative* OR co-operative* OR syndicate* OR “agricultural sector” OR “agricultural trade” OR “floriculture” OR “crop production” OR “agricultural product*”)

# 7
TS=(coffee OR cocoa OR tea OR infusion* OR “yerba mate” OR c$amomile OR sugar* OR fruit* OR vegetable* OR banana* OR pineapple* OR mango* OR coconut* OR apricot* OR nut* OR cashew* OR “shea butter” OR argan OR rice OR quinoa OR bean* OR chickpea* OR “red kidney” OR lentil* OR soy* OR herb* OR spice* OR “olive oil” OR olive* OR wine OR honey OR cotton OR flower* OR floriculture OR “palm oil” OR “oil palm” OR beef OR cattle OR dairy OR livestock OR animal OR poultry OR pork OR eggs OR “non timber forest product” OR “NTFP” OR ((crop* OR forest*) NEAR/2 produc*))

8
#7 OR #6

#9
TS=(fertiliz* OR fertilis* OR pesticide* OR herbicide* OR *insecticide* OR input* OR compost OR amendment* OR “spray drift” OR “integrated pest management” OR “IPM” or “pest management” OR nitrogen OR phosphorus OR erosion OR groundcover OR “ground cover” OR “stream* vegetation” OR “ecological condition” OR “erosion control” OR “soil organic matter” OR “ground disturbance” OR “soil carbon” OR “cation exchange capacity” OR road OR “soil quality” OR “bulk density” OR “infiltration rate” OR ((“carbon mineralization” OR “nitrogen mineralization” OR microb* OR enzym* OR arthropod* OR *invertebrate* OR biomass OR *divers* OR “carbon content” OR “carbon storage”) NEAR/2 soil))

10
#9 AND #8 AND #5

Google Scholar – Search conducted on 3/11/2020

(fertilizer|pesticide|erosion|"soil organic matter"|"soil health"|"soil quality"|"integrated pest management"|herbicide|insecticide) AND (fairtrade|"rainforest alliance"|"global gap"|utz|"better cotton initiative"|"cafe practices"|"fsc"|"nespresso AAA")

Antibiotic use

CABI – Search conducted on 10/24/2019

1 = ((“certification” OR “quality standards” OR “quality label?ing” OR “sustainability standards”)) AND yr:[2009 TO 2019]

2 = ((private OR company OR companies OR “supply chain*” OR corpor* OR food OR commodity*) AND (collective OR group OR industry OR aspiration OR commitment OR pledge OR declarati* OR “sourcing standard*” OR code* OR “code* of conduct” OR policy OR ban OR moratori* OR “market exclusion” OR agreement OR sanction*)) AND yr:[2009 TO 2019]

3 = (((fair* OR ethic* OR alternative OR sustainab* OR responsib* OR specialty OR eco OR ecologic*) NEAR (certify* OR standard* OR label* OR seal* OR scheme* OR trad* OR market* OR “value chain*” OR commodity*))) AND yr:[2009 TO 2019]

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5 = OR/1-4

6 = ((farm* OR agriculture* OR livestock OR cattle OR grower* OR ranch OR fish* OR producer* OR smallholder* OR small-holder OR “small holder” OR cooperative* OR co-operative* OR syndicate*)) AND yr:[2009 TO 2019]

7 = ((beef OR cattle OR dairy OR livestock OR animal OR poultry OR pork OR egg* OR fish* OR mollusk* OR mussel* OR salmon OR seafood OR aquacultur* OR shellfish OR shrimp* OR prawn* OR crab* OR catfish OR pangasius OR sardine* OR tilapia)) AND yr:[2009 TO 2019]

8 = OR/6-7

9 = ((antibiotic* OR *microb* OR ((outbreak* OR bacteria* OR infect*) NEAR treat*)) AND yr:[2009 TO 2019]

10 = 5 AND 8 AND 9

11 = ((cc:aa000 OR cc:hh410 OR cc:ll110 OR cc:ll120 OR cc:ll130 OR cc:ll821 OR cc:mm120 OR cc:rr130)) AND yr:[2009 TO 2019]

12 = 10 AND 11

Web of Science – Search conducted on 10/14/2019

# 1
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5
#4 OR #3 OR #2 OR #1

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8
#7 OR #6

#9
TS=(antibiotic* OR *microb* OR ((outbreak* OR bacteria* OR infect*) NEAR/2 treat*))

10
#9 AND #8 AND #5

Google Scholar – Searches conducted on 3/18/2020

1. (antibiotic|antimicrobial|"antibiotic resistance"|"antibiotic treatment") AND (fairtrade|"rainforest alliance"|"best aquaculture practices"|"global roundtable for sustainable beef"|"GRSB"|"stewardship council"|"american grassfed"|"food and ranch certification program")

2. (antibiotic|antimicrobial|"antibiotic resistance"|"antibiotic treatment") AND (“sustainability certification”|certification|”sustainably certified”|certified|“sustainability standard”) AND (livestock|aquaculture|cattle|fish)

Annex C – List of eligible market-based sustainability approaches

Agrochemicals and soil health

Voluntary Sustainability Standards

4C Association
Aid by Trade
Alliance for Water Stewardship (AWS)
Aluminium Stewardship Initiative (ASI)
American Grassfed
Audubon G.U.L.F. RFM Certification Program
Australian Forest Certification Scheme
Better Cotton Initiative (BCI)
Biomass Biofuels Voluntary Scheme (2BSvs)
Bird Friendly Coffee
Bonsucro
Canadian Beef Roundtable
Cerflor Forest Certification Program (Brazil)
Chilean Sustainable Forest Management Certification System (Certfor)
Clean Marine Green Leaf Eco-Rating Program
Cotton made in Africa
Equitable Origin
EU Biofuels Requirement
Eurep GAP
Fairtrade International
Fair Trade USA
FairWild
Florimark
FlorVerde
Flower Label Program (FLP)
Food Alliance Certified
Food and Ranch Certification Program
Forest Stewardship Council (FSC)
GEO Foundation
Global GAP
Global Infrastructure Basel
GoodWeave
IFFO RS
International Sustainability and Carbon Certification (ISCC)

Linking Environment And Farming (LEAF)
Living Forest Standards
Local Food Plus (LFP) Certified
Potato Sustainability Initiative
Program for Endorsement of Forest Certification (PEFC)
Proterra Foundation
Rainforest Alliance (RA)
Responsible Jewellery Council (RJC)
Roundtable on Responsible Soy (RTRS)
Roundtable on Sustainable Biomaterials (RSB)
Roundtable on Sustainable Palm Oil (RSPO)
SD-Vista (Verra Standard)
SIP Certified
Sustainable Forestry Initiative (SFI)
Textile Exchange
The Gold Standard
Trustea
Union for Ethical BioTrade (UEBT)
UTZ

Bans, moratoria, and multi-party agreements (for specific commodities/areas)

Amazon Soy Moratorium
Ban on Uzbekistan Cotton
Better Growth with Forests
Brazil Cattle Agreements
Cocoa and Forests Initiative (CFI)
Commitment to Action (C2A)
Financial Sector Engagement initiative
Joint Solutions Project (Chile)
Singapore Alliance for Sustainable Palm Oil
Value Beyond Value Chains

Specific national plans, policies and platforms

Africa Palm Oil Initiative (APOI) - TFA 2020
Colombia deforestation-free palm oil pledge and program
Global Coffee Platform (GCP)
Indonesia Sustainable Palm Oil Platform (FoKSBI)
Latin America Initiative - TFA 2020
Papua New Guinea Sustainable Palm Oil Platform (PNGPOP)
Southeast Asia Initiative - TFA 2020
Sustainable Coffee Challenge
Sustainable Commodities National Platform - Paraguay
Sustainable Pineapple National Platform Initiative - Costa Rica

Sustainable sourcing codes

Consumer Goods Forum (CGF)
Ethical Trading Initiative (ETI)
Marks and Spencer Sourcing Code
Nespresso AAA
Nike Code of Conduct
Partnership for Sustainable Textiles
Sainsbury's Sourcing Code
Starbucks CAFÉ practices
Unilever Sustainable Agriculture Code
Walmart sustainable sourcing programs (including Project Gigaton)

Jurisdictional approaches

IDH Verified Sourcing Areas

Public or quasi-public sustainability standards

Green Food Program (China)
Indonesia Sustainable Palm Oil Standard (ISPO)
Malaysia Sustainable Palm Oil Standard (MSPO)
Sistem Verificasi Legalitas Kayu (SVLK)

Supplementary VSS tools

EnVeritas
Palm oil innovation group (POIG)
RSPO Jurisdictional Palm Oil Certification
RSPO Next
SAI Platform
Sustainable Agriculture Network (SAN)

Supply chain investment programs

Asia Pacific Resources International Holdings Limited (APRIL)
Asia Pulp & Paper Group (APP)
Cocoa Life (Mondelez)
Coffee Made Happy (Mondelez)
Ethical Tea Partnership (ETP)
Fair Wear Foundation
Novo Campo

Sustainability requirements within trade or procurement policies

Amsterdam Declaration
EU biofuels requirements

Specific global or regional implementation norms for responsible supply chains

Accountability Framework initiative
Collaboration for Forests and Agriculture (CFA)

Global Roundtable for Sustainable Beef (GRSB)
High Carbon Stock Approach (HCSA)
High Conservation Value (HCV) approach
UN Global Compact
UN Guiding Principles on Business and Human Rights

Sustainability performance and progress reporting

CCBA Sustainable Landscapes Rating Tool
CI Landscape Assessment/ Accounting Framework
Field to Market
GCF Impact Platform
Global Reporting Initiative (GRI)
Sustainable Apparel Coalition (SAC)
US State Dept. Commodities/Jurisdiction Approach

Antibiotic use

Voluntary Sustainability Standards

Alaska Responsible Fisheries Management (RFM) Certification Program
American Grassfed
Aquaculture Stewardship Council (ASC)
Best Aquaculture Practices (BAP)
Canadian Beef Roundtable
Clean Marine Green Leaf Eco-Rating Program
Fairtrade International
Fair Trade USA
FairWild
Food Alliance Certified
Food and Ranch Certification Program
Friend of the Sea
Global GAP
Iceland Responsible Fisheries Management (IRFM) Certification Programme
Local Food Plus (LFP) Certified
Marine Aquarium Council (MAC)
Marine Stewardship Council (MSC)
Rainforest Alliance (RA)
Salmon-Safe
Sustainable Eel Group
Union for Ethical BioTrade (UEBT)

Bans, moratoria, and multi-party agreements (for specific commodities/areas)

Brazil Cattle Agreements
Commitment to Action (C2A)

Dolphin Safe/ Dolphin Friendly
Joint Solutions Project (Chile)
Value Beyond Value Chains

Specific national plans, policies and platforms

Blue Swimming Crab & Octopus Philippines Platform
Large Pelagic Sustainable Fisheries Platform - Costa Rica
Latin America Initiative - TFA 2020
Small and Large Pelagic Fisheries Platform - Ecuador
Southeast Asia Initiative - TFA 2020
Sustainable Commodities National Platform - Paraguay
Tuna & Blue Swimming Crab Platform Indonesia

Sustainable sourcing codes

Consumer Goods Forum (CGF)
Ethical Trading Initiative (ETI)
Sainsbury's Sourcing Code
Walmart sustainable sourcing programs (incl Project Gigaton)

Jurisdictional approaches

IDH Verified Sourcing Areas

Supply chain investment programs

Asia Pacific Resources International Holdings Limited (APRIL)
Novo Campo
Sustainable Fisheries Partnership (SFP)

Sustainability requirements within trade or procurement policies

Amsterdam Declaration

Specific global or regional implementation norms for responsible supply chains

Accountability Framework initiative
Global Roundtable for Sustainable Beef (GRSB)
UN Global Compact

Sustainability performance and progress reporting

CCBA Sustainable Landscapes Rating Tool
CI Landscape Assessment/ Accounting Framework
Field to Market
GCF Impact Platform
Global Reporting Initiative (GRI)
Global Salmon Initiative (GSI)
Seafood Watch (SW)
US State Dept. Commodities/Jurisdiction Approach


A55

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Page 28 © LEAF (Linking Environment And Farming)| Field

Page XVI © Sustainable Agriculture Network | Cattle, Costa Rica