Global Journal of Agricultural Research

Vol.9, No3, pp.35-61, 2021

Print ISSN: 2053-5805(Print),

Online ISSN: 2053-5813(Online)

REVIEW ON ORGANIC FARMING VS. CONVECTIONAL FARMING SYSTEM

Israel Zewide and Abde Sherefu

[1.]Department of Natural Resource Management, College of Agriculture, Mizan-Tepi Unversity and Natural Resource Management, P,O.Box 260, Mizan-Aman, Ethiopia

1 Department of Plant science , College of Agriculture, Mizan-Tepi Unversity and Natural Resource Management P,O.Box 260, Mizan-Aman, Ethiopia

ABSTRACT: *Organic farming is a type of agriculture or farming which avoids the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives. Organic standards are designed to allow the use of naturally occurring substances while prohibiting or strictly limiting synthetic substance. Organic farming is an important topic for society, so this paper shows some results arisen from a wider research on economic and environmental sustainability of organic farming. It focuses on organic and conventional farming comparison through different information and review. In this review, we examine the debate surrounding the role for organic agriculture in future food production systems. Typically represented as a binary organic and conventional question, this debate perpetuates an either/or mentality. We question this framing and examine the organic and conventional cropping systems comparisons. The review assesses current knowledge about how these cropping systems compare across a range of metrics related to for sustainability goals: productivity, environmental health, economic viability, and quality of life. We conclude by arguing for reframing the debate, recognizing that farming systems fall along gradients between three philosophical poles industrial, agrarian, and ecological and that different systems will be appropriate in different contexts. Regardless of evidence for lower yields in organic crop systems, we found considerable evidence for environmental and social benefits. Given these advantages, and the potential for improving organic systems, we come back calls for increased investment in organic and ecologically based farming systems research and extension.*

KEYWORDS: agro ecology, cropping system, debate, diversified farming food production, sustainability, synthetic

INTRODUCTION

Organic farming is a form of agriculture that relies on sustainable techniques to enhance the natural fertility of a farm, including crop rotation, companion planting, biological pest control, and naturally-sourced fertilizers such as compost, manure, green manure, and bone meal. Pest-control measures such as mixed crops and fostering natural insect predators, are employed, while it excludes the use of synthetic petrochemical fertilizers and pesticides, plant growth regulators such as hormones, antibiotic use in livestock, genetically modified organisms, human sewage sludge, and nanomaterial. The agricultural approach emphasizes sustainability, openness, independence, health, and safety. (Alvin et al., 2018*)*.

A crop can be classified as conventional if synthetic chemicals are used to maintain the plants. A significant amount of chemical and energy input is required in conventional agriculture to produce the highest possible yield of crops. Conventional agriculture was developed to make farming more efficient, but achieves that efficiency at a major cost to the environment. The goal of conventional agriculture is to maximize the potential yield of crops. This is achieved through the application of synthetic chemicals, genetically modified organisms, and a number of other industrial products. Production of these crops is beneficial to nothing but food security and economy. Since the goal of conventional agriculture is to maximize yields, environmental health and biodiversity are usually not preserved (Alvin et al., 2018).

The main aspect of organic farming is that inorganic fertilizers, genetically modified products and pesticides are not used in the production (Council Regulation, 2007). European Union (EU) has a common agricultural policy (CAP) which sets the standards for all the member states regarding organic production and certification (European Commission, 2014b). Besides the EUs certification for organic production, Sweden has a national organic certification called KRAV which has more requirements than the EUs certification (KRAV, 2015a). If farmers get an organic certification they can have environmental support, e.g. economic compensation, which is distributed to the farmer and is funded by the EU and the Swedish government (Jordbruksverket, 2015). Today the Swedish government is supporting organic production with about 500 million Swedish kronor per year (Kirchmann *et al*, 2014).

Sweden's government has as an environmental goal to reach a 20 % organic production by 2010 (Miljömal, 2015a) but in 2014 the amount of organically grown farmland in Sweden was 17 % (Statistiskacentralbyran, 2015a). The demand for organic products in Sweden has increased between 2012 and 2013 with almost 12 % (Fagerberg *et al*, 2014). But the conversion to organic farming has decreased (StatistiskaCentralbyran, 2015a). Scania (Skane), a region where half of the land is farmland (Hall *et al.*, 2014), has 6 % organic farming which is the lowest amount compared to other regions in Sweden (Statistisk and Centralbyran, 2015a). Organic farming was first developed from natural philosophy, not science, with the assumptions that certain organic farming methods would lower the negative impacts on the environment without it being tested or proven scientifically (Kirchmann *et al*, 2014). Today it is stated that organic production is built on science but (Kirchmann et al, 2014) discuss that there still is certain assumptions about environmental benefits in organic production that is not scientifically based which is a subject greatly debated in the scientific community. Organic agriculture is a production system that regenerates the health of soils, ecosystems, and people. Organic farmers rely on natural processes, biodiversity, and cycles adapted to local conditions rather than the use of synthetic inputs like chemical fertilizers, pesticides, and herbicides. GMOs are not allowed in organic (USDA, 2007).

Organic agriculture can be defined as: an integrated farming system that strives for sustainability, the enhancement of soil fertility and biological diversity whilst, with rare exceptions, prohibiting synthetic pesticides, antibiotics, synthetic fertilizers, genetically modified organisms, Since 1990 the market for organic food and other products has grown rapidly, reaching $63 billion worldwide in 2012 (Helga *et al* 2013).

Organic food is increasing in popularity. The growing demand is mainly attributable to consumer concerns about negative implications of conventional agriculture for human health and the environment. Especially in developed countries, most consumers consider organic food to be safer and healthier than conventionally produced food (Funk and Kennedy 2016). Rich-country consumers often also perceive organic farming to be better for the environment, climate protection, and animal welfare (Seufert et al, 2017).

In Europe in particular, organic farming has such a positive public image that it is commonly touted as the paradigm for sustainable agriculture (Mercati, 2016). A representative survey carried out in Germany showed that approximately 50% of the population considers wider adoption of organic agriculture as an important strategy to fight global hunger (Klumper et al., 2013). The same survey revealed that agrochemicals and genetically modified organisms (GMOs) are often perceived as major threats to food security. In developing countries, the awareness of organic agriculture is still lower, but European perceptions and food preferences are also starting to gain ground, especially among better-off urban consumers (Greenpeace, 2015 and Probst et al., 2012).

In the academic literature, the views are more nuanced, but the conclusions about the role of organic agriculture for global sustainable development differ widely. Some consider organic agriculture as inefficient and mainly driven by ideology (Connor and Mınguez 2012, Lotter 2015 , Trewavas 2001). Others see great potential in organic farming to feed the world in an environmentally friendly way (Badgley *et al*. 2007, Reganold and Wachter 2016).

Over the last several decades, green revolution technologies, including high-yielding crop varieties and complementary inputs such as synthetic fertilizers, pesticides, and irrigation water, have contributed substantially to productivity growth in agriculture and improvements in global food security (Evensonr and Gollin 2003 and Qaim 2017). Nevertheless, approximately 800 million people are still chronically undernourished, most of them living in Asia and Africa (FAO 2017). Over the next few decades, the demand for food will increase further due to population and income growth. In addition, plant-based products are increasingly being used as renewable resources. To keep up with this rising demand, it is estimated that global agricultural production will have to increase by at least 60% and possibly up to 100% until 2050 (Godfray *et al.* 2010 and Hertel, 2015).

This is a major challenge because land, water, and other natural resources are becoming increasingly scarce. Furthermore, the input-intensive agricultural production systems observed

Vol.9, No3, pp.35-61, 2021
Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

in many parts of the world are responsible for or at least contribute to major environmental problems, such as land degradation, biodiversity loss, water pollution, and climate change (Foley *et al*, 2011). Increasing production while reducing the environmental footprint will require profound changes in food and agricultural systems and the types of technologies used. But is organic agriculture the solution? This question is addressed here by reviewing the extensive literature on various aspects of certified organic farming, including economic, social, environmental, and health effects. While organic is fundamentally different from conventional because of the use of carbon based fertilizers compared with highly soluble synthetic based fertilizers and biological pest control instead of synthetic pesticides, organic farming and large-scale conventional farming are not entirely mutually exclusive. Many of the methods developed for organic agriculture have been borrowed by more conventional agriculture. For example, Integrated Pest Management is a multifaceted strategy that uses various organic methods of pest control whenever possible, but in conventional farming could include synthetic pesticides only as a last resort "Integrated Pest Management"(2013).

Objective

- To review how organic farming vs. conventional farming.

LITERATURE REVIEW

Principles and Adoption of Organic Agriculture

Historical Background

The idea of organic agriculture evolved in the early twentieth century in the context of urbanization and the increasing use of agrochemical inputs in farming. The organic movement started in German- and English-speaking countries and was influenced by different groups that promoted rural traditions and the use of biological (instead of synthetic) fertilizers (Vogt 2007). For several decades, the organic movement remained very small, but it has gained popularity since the 1970s with rising public concerns about health and environmental effects of industrialized farming (Lockeretz 2007). In the following decades, governments in several rich countries started to subsidize the organic sector. As a result, the market share of certified organic products increased. In the European Union and the United States, policy measures to support organic farming include governmental regulations and standards, direct subsidies to organic producers, research funding, and sponsorship of communication instruments such as promotion campaigns and organic labeling. The rationale for government interventions is to reward organic farmers for their superior environmental performance and compensate for related increases in production costs or decreases in yield (Stolze and Lampkin 2009). More recently, policy support has also facilitated the adoption of organic standards in developing countries. Domestic governments and western development agencies have launched a number of projects to link smallholder farmers to organic export markets (Eva-Marie *et al*, 2019).

Principles of Organic Agriculture
Today, more than 100 countries publicly support organic standards (Seufert *et al*, 2017). Additionally, several private organic standards exist. Governmental and private standards are typically based on the standards developed by the International Federation of Organic Agriculture Movements (IFOAM) (http://www.ifoam.bio/en). Hence, most organic standards are similar, even though they can differ in specific details. Organic standards cover different are such as crop production, animal husbandry, wildlife collection, beekeeping, aquaculture, and processing, among others. The standards involve activities that are prohibited or restricted and other activities that are required or recommended. The cornerstone of organic production systems are balanced crop rotations with legumes, recycling of nutrients (e.g, through mixed farming), and the use of organic fertilizers. Use of synthetic fertilizers and chemical pesticides is prohibited. In livestock production, the animals must be fed with organic fodder, preferably from the same farm, and provided with sufficient space and access to outdoor areas (Eva-Marie *et al*, 2019).

Compliance with organic standards is verified on an annual basis through farm inspections undertaken by accredited certification agents (Seufert *et al.* 2017). For this purpose, records on all farming activities must be kept. In developed countries, certification of individual farms is commonplace. In developing countries, certification is often group based, especially in the small farm sector. Group certification reduces the costs for individual farmers as well as the transaction costs for certifiers and buyers (Jena *et al.* 2012 and Meemken *et al*. 2017b).

Adoption of Organic Agriculture
Over the past 15 years, the global area under certified organic agriculture has increased substantially, from 15 million ha in 2000 to 51 million ha in 2015. Nevertheless, in 2015, organic agriculture accounted for only 1% of the total agricultural land worldwide. With almost 23 million ha, Australia is the country with the largest certified organic area; most of the organic area in Australia is extensively managed grassland (Eva-Marie *et al*, 2019). Other countries with relatively large organic areas include Argentina, the United States, and Spain. A breakdown by crop species shows that organic production plays a larger role for permanent crops, such as berries, coffee, and olives, than for annual crops such as cereals and vegetables. While the largest share of the global organic area is found in developed countries 88% of the organic farmers (2.1 million out of 2.4 million) live in developing countries in Asia, Africa, and Latin America. The countries with the largest number of organic farmers are India (0.6 million), Ethiopia (0.2 million), and Mexico (0.2 million). Organic farmers in developing countries mainly produce traditional export crops, such as coffee and tea (Willer and Lernoud 2017).

Several studies have analyzed factors that influence farmers' decisions to switch from conventional to organic practices in developed and developing countries. Access to government subsidies for organic farming tends to play an important role (Brenes-Munoz *et al*, 2016). However, government subsidies can also add to policy risk, which may reduce adoption under certain conditions (Kuminoff and Wossink 2010). In addition to policy risk, organic farming may be associated with higher production risk, because certain risk-reducing inputs are not allowed (Serra *et al*, 2008). For instance, chemical pesticides help to reduce pest damage but are prohibited in organic agriculture. Indeed, studies showed that adopters of organic practices tend to be more risk loving than non-adopting farmers (Kallas *et al*. 2010 and Serra *et a*. 2008).

Other important adoption determinants include access to information and to high-value certified markets in which buyers are willing to pay significant price premiums for organic products (Lapple 2010, Wollni and Andersson 2014). Especially in the small farm sector of developing countries, adoption of organic standards crucially depends on development initiatives to provide training and marketing support to farmers (Bolwig *et al*. 2009). In line with the increase in the global organic land area, sales of organic products have also increased. Since 2000, global organic retail sales have quadrupled, reaching US$82 billion in 2015. Demand for organic products is concentrated in North America and Europe.(Eva-Marie *et al*. 2019)

In Europe, the largest organic markets in terms of total retail sales are Germany and France. However, in terms of per capita expenditures on organic products, the leading countries are Switzerland, Denmark, and Sweden (Willer and Lernoud 2017). In most developing countries, demand for organic products is negligible, although increasing in certain high-income segments of the population. Poor people can hardly afford organic products due to significantly higher prices. On average, organic products are priced 50% above conventional products, reflecting higher costs in production, processing, and distribution (Seufert *et al.* 2017). Price differences between organic and conventional tend to be more pronounced for animal products than for fruits, vegetables, and processed foods (Carlson and Jaenicke 2016).

Can Organic Agriculture Feed The World?

Many see organic agriculture as the most sustainable form of farming and as the paradigm for global food production in the future. Hence, the question of whether organic agriculture alone could actually feed the world with its 7.5 billion people today, and likely over 9 billion people by 2050, arises time and again (Badgley *et al*. 2007, Connor 2008, Erb *et al*. 2016, Seufert and Ramankutty 2017, Muller *et al*. 2017 and Taheri *et al*. 2017). Given that organic farming today only accounts for 1% of the agricultural land, a total conversion to organic agriculture does not seem to be a realistic scenario in the foreseeable future, but it is nevertheless an interesting thought experiment (Eva-Marie *et al*. 2019).

Environmental Effects of Organic Farming

Agricultural production contributes to various environmental problems such as climate change, biodiversity loss, soil degradation, and water pollution (Foley *et al*. 2011). It is widely believed that organic agriculture causes fewer negative environmental externalities than conventional agriculture, which is also the main reason why many governments subsidize the organic sector. In this section, we review the evidence of the effects of organic farming on various environmental aspects. (Eva-Marie *et al*. 2019)

Use Efficiency

Approximately 40% of the global ice-free land is used for agricultural production (Foley *et al.* 2011). Continuous land-use change (e.g. deforestation) is associated with various environmental problems, especially the loss of biodiversity and the release of soil carbon into the atmosphere. Thus, balancing food production and environmental goals will increasingly require using land and other natural resources more efficiently. Organic systems have lower land-use efficiency than conventional systems. As discussed above, organic crop yields are lower than conventional yields on average. In addition, organic crop rotations typically include crops that are not suitable for human consumption. Finally, organic animal husbandry is characterized by longer production cycles and lower animal growth rates, meaning that larger quantities of fodder and more land for fodder production are required per unit of organic meat (Treu *et al*. 2017). Land-use requirements are also relevant when assessing other environmental effects of organic and conventional production systems. Therefore, environmental impacts are typically expressed per unit of land and per unit of output, where the latter tries to account for lower land-use efficiency in organic systems. Given the rising demand for food and agricultural products, measuring per unit of output seems more relevant to assess environmental impacts from a global perspective. However, even this approach probably underestimates the environmental effects that large-scale conversion to organic agriculture might have. Today, only a marginal share of the global agricultural land is certified organic. Large-scale conversion to organic would likely require bringing more natural habitats into agricultural production. Such additional land-use change would be associated with environmental costs that are not fully accounted for by simply expressing per unit of output (Leifeld 2016).

Energy Use and Greenhouse Gas Emissions

Approximately 25% of the anthropogenic greenhouse gas (GHG) emissions are attributable to food production (Edenhofer *et al.* 2014). Carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) emissions accrue during the combustion of fossil fuels (e.g. for the production of mineral fertilizer and the use of agricultural machinery), soil chemical processes, and animal digestion, among others (Gomiero *et al*. 2011). Energy use and GHG emissions from agriculture are typically evaluated through life cycle assessments until a product leaves the farm (Meier *et al.* 2015 and Smith *et al*. 2015). The evidence suggests that organic agriculture uses less energy per unit of land, and to a lesser extent, also per unit of output than conventional agriculture. This difference is mainly attributable to the nonuse of synthetic fertilizers and pesticides in organic systems. Fuel use for agricultural operations is similar across systems. However, for certain crops (especially vegetables) more fuel is sometimes required in organic production, when repeated mechanical or thermal weed control becomes necessary (Lynch *et al.* 2011, Scialabba and Muller-Lindenlauf 2010 and Smith *et al*. 2015). This may also lead to higher overall energy use in organic systems in certain situations (Lee *et al*. 2015). Concerning GHG emissions, most studies conclude that organic farming has lower impacts when expressed per unit of land but not when expressed per unit of output. Generally, organic systems are characterized by lower nitrogen inputs, and thus lower N2O emission potential. However, balancing nutrient supply and plant demand is typically more challenging in organic systems;

@ECRTD-UK https://www.eajournals.org/ https://doi.org/10.37745/gjar.2013

Vol.9, No3, pp.35-61, 2021

Print ISSN: 2053-5805(Print),

Online ISSN: 2053-5813(Online)

oversupply of nitrogen from organic fertilizer may also lead to significant N2O emissions, while undersupply leads to lower yields (Clark and Tilman 2017, Lynch *et al.* 2011 and Skinner *et al.* 2014).

In crop production, soil carbon stocks and sequestration rates were found to be significantly higher in organic than in conventional systems (Gattinger *et al.* 2012 and Lori *et al*. 2017). In livestock production, less intensive organic husbandry systems lead to larger quantities of manure per unit of meat, and thus higher methane and N2O emissions (Treu *et al.* 2017). Overall, the evidence does not support the widely held notion that organic agriculture is more climate friendly than conventional agriculture (WBA 2016).

Nutrient Leaching and Water Quality

Nutrient leaching is a problem, especially in regions with intensive agriculture, as it causes eutrophication of water bodies and marine ecosystems (Halberg 2012). Nitrate (NO3 −) leaching under organic management was found to be lower per unit of land but not per unit of output The overall eutrophication potential per unit of output, measured in terms of phosphate (PO4) equivalents, and the acidification potential, measured in terms of sulfur dioxide (SO2) equivalents, were even found to be higher in organic systems (Clark and Tilman 2017). Nonuse of synthetic fertilizers is generally associated with lower leaching potential (Lori *et al*. 2017 and Niggli 2015), but again, avoiding mismatches between nutrient supply and plant demand can be challenging in organic systems, potentially leading to greater nutrient losses (Gomiero *et al*. 2011, Halberg 2012 and Tuomisto *et al*. 2012). Concerning pesticides, as synthetic pesticides are banned in organic farming, the risk of pesticide pollution of water bodies is lower (Reganold and Wachter 2016). However, certain non synthetic pesticides, which are used in organic farming, can also have negative effects for aquatic life. For instance, in organic horticultural production copper-based solutions are widely used to control fungal diseases (Niggli 2015).

Soil Quality

Millions of hectares of previously fertile land have become unsuitable for agricultural production because of soil degradation (e.g, erosion), often as a result of mismanagement (Halberg 2012). Organic practices such as the application of organic matter (e.g., green or animal manure) and longer and more diverse crop rotations with cover and catch crops can help to reduce soil erosion and fertility decline (Lori *et al*. 2017 and Niggli 2015). Meta-analyses and results from long-term field trials confirm that organically managed fields have higher contents of organic matter and larger and more active soil microbial communities both key indicators of soil quality. (Eva-Marie *et al*. 2019) Increased soil fertility: biodynamic farms had better soil quality: greater in organic matter, content and microbial activity, more earthworms, better soil structure, lower bulk density, easier penetrability, and thicker topsoil (Reganold *et al.* 1993); agricultural productivity doubled with soil fertility techniques: compost application and introduction of leguminous plants into the crop sequence (Dobbs and Smolik, 1996; Drinkwater, 1998; Edwards, 2007);

Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Biodiversity
Agricultural intensification and homogenization of landscapes have significantly contributed to biodiversity loss (Bengtsson et al. 2005, Halberg 2012). There is large agreement that organic farms are more biodiversity (Hole *et al*. 2005, Mader *et al*. 2002, Pimentel *et al*. 2005, Schneider *et al*. 2014 and Tuck *et al*. 2014), which is due to lower pesticide use, longer crop rotations, and more semi natural landscape elements (e.g, hedges) (Niggli 2015). Meta-analyses suggest that species richness (number of species) and species evenness (relative abundance of different species) are both significantly higher on organic farms than on conventional farms. Large differences were found when high-intensity conventional systems were taken as the reference (Bengtsson *et al.* 2005 and Tuck *et al*. 2014). However, the biodiversity benefits diminish with increasing intensity of organic production systems (Gabriel *et al*. 2013).
Disagreement exists whether the benefits of organic farming also diminish with increasing scale (Bengtsson *et al.* 2005, Schneider *et al*. 2014 and Tuck *et al*. 2014). As mentioned, because of lower yields, large-scale conversion to organic agriculture would likely imply further loss of natural habitats. It is largely agreed that the biodiversity gains from organic production cannot offset the biodiversity loss associated with additional land-use change (Gabriel *et al*. 2013, Green *et al.* 2005, Mondelaers *et al.* 2009 and Schneider *et al*. 2014). The "land sharing" versus "land sparing" debate is complex and requires site-specific solutions, which is why simplistic global prescriptions are inappropriate (Phalan *et al.* 2011 and Tuck *et al*. 2014).

Yield Effects

Estimated Yield Gaps
When evaluating the potential of organic agriculture to contribute to sustainable development, a central question concerns the yields obtained in comparison to conventional farming. Estimating yield effects of organic practices is not easy, as confounding factors have to be controlled for. For instance, when organic farmers obtain lower yields, this may be due to the organic practices, but it is also possible that the farmers are less talented or operate in less-favorable environments than their conventional colleagues (Eva-Marie *et al*. 2019).

In the latter case, organic farmers would have lower yields anyway, even when applying the same technology, so the yield gap of organic farming practices would be overestimated. On the other hand, it is also possible that organic farmers are systematically more talented than their conventional counterparts, which would lead to underestimated yield gaps when simply comparing observed organic with conventional yields (Eva-Marie *et al*. 2019). Available studies show a wide range of results, depending on the particular context. In some situations, organic yields were found to be higher than conventional yields, whereas in other situations they were considerably lower. More recently, a few review papers have tried to synthesize the evidence. A first attempt in this direction was a study by Badgley *et al*. (2007). The authors used results from various sources to conclude that organic agriculture had 33% higher average crop yields than conventional agriculture at the global level(Eva-Marie *et al*. 2019).

In developed countries, organic yields were 9% lower than conventional yields, but in developing countries, the authors claimed that organic practices would increase crop yields by 74% (Badgley *et al*. 2007). However, this study was heavily criticized on various grounds (Cassman 2007, Connor 2008, Goulding and Trewavas 2009). Many of the studies included in the review by Badgley *et al*. (2007) did not meet minimum scientific standards in terms of experimental design (Cassman 2007). Other relevant studies were simply ignored (Goulding and Trewavas 2009). For developing countries, Badgley *et al*. (2007) mostly compared yields of crops that had received high levels of organic nutrients as the organic version with crops that had received very little or no fertilizer as the conventional version (Connor 2008). Hence, despite being highly cited, the results of Badgley *et al*. (2007) are not reliable and meaningful. Across all crops, mean yield gaps of organic agriculture are in the magnitude of 19–25%. Considerable differences can be observed across different crop species, with legumes and fruits showing smaller yield gaps than cereals and root and tuber crops. (Eva-Marie *et al*. 2019). There is some evidence that the yield gap increases as conventional yields increase (De Ponti *et al*. 2012). Under best management practices for both systems, yield gaps do not seem to differ significantly between developed and developing countries (Ponisio *et al*. 2015). However, in all three meta-analyses, observations from developing countries are heavily under represented (Seufert and Ramankutty 2017). so statements about geographic differences of yield gaps need to be interpreted with caution. Longer-term research was recently started to improve knowledge about the productivity effects of organic farming in developing countries (Forster *et al*. 2013). One relevant issue when comparing yield levels between organic and conventional agriculture is the time period that the original studies cover. It is sometimes assumed that yields would decline shortly after conversion to organic practices but would then recover after a while due to gradually improving soil conditions in organic farming. However, the evidence to support this assumption is weak. While some studies report organic yield increases over time, others find no changes or even decreasing yields in longer-term studies (De Ponti *et al*. 2012 and Mader *et al*. 2002). ¨

Explaining Yield Gaps

Apart from sunlight and favorable temperatures, plants need a range of different nutrients to grow well, especially nitrogen, phosphorus, potassium, and several micronutrients. In addition, soil texture and composition, water availability, and problems due to pests and diseases matter. Almost all of these parameters may differ between organic and conventional practices; hence, it is not surprising that yield levels differ as well. As mentioned, organic standards prohibit the use of synthetic fertilizers. Although all the required nutrients can, in principle, also be provided through organic fertilizers, nutrient management is more difficult in organic production systems (Niggli 2015). Organic systems are often found to be limited in nitrogen and phosphorus (Berry *et al*. 2002 and Oehl *et al.* 2002).

The release of plant-available nitrogen from organic sources is slow and can often not keep up with the nitrogen demand during peak crop growth periods (Seufert *et al*. 2012). The amount

Vol.9, No3, pp.35-61, 2021

Print ISSN: 2053-5805(Print),

Online ISSN: 2053-5813(Online)

of phosphorus provided in organic systems is also sometimes insufficient to replenish the quantities lost due to harvest (Oehl *et al*. 2002). In general, providing the right mixture of nutrients to optimally support plant growth is more complicated in organic systems because the nutrient ratio of organic inputs can only be influenced to a very limited degree (Seufert and Ramankutty 2017). Nutrient limitations are an important factor to explain the observed yield gaps in organic agriculture. Against this background, lower-than-average yield gaps observed for legumes and fruits are plausible. Legumes can fix atmospheric nitrogen and are hence less dependent than other crops on externally added nitrogen. Fruits grow on trees that have longer growing seasons and extensive root systems and are hence better able to absorb nutrients in synchrony with crop demand (Seufert *et al*. 2012).

In terms of water availability and use, organic systems tend to have an advantage because soils managed with organic methods show better water-holding capacity and higher rates of water infiltration. This is also one reason why organic systems are often said to be more resilient and have higher yield stability, even under drought conditions (Gomiero *et al*. 2011 and Niggli 2015). On the other hand, organic systems are sometimes more susceptible to pest outbreaks, which can lead to yield losses and higher yield variability (Seufert and Ramankutty 2017). The ban of chemical pesticides and GMOs in organic agriculture limits the tools available to farmers for effectively controlling weeds, insect pests, and plant diseases. Hence, in high pest pressure environments, and where pests and diseases that are difficult to control with biological methods are found, yield gaps of organic agriculture are higher than in low pest pressure environments (Eva-Marie *et al*. 2019).

External Validity of Estimated Yield Gaps

Most of the data that rigorously compare crop yields in organic and conventional agriculture stem from experimental trials carried out on research stations. Experimental yields are often higher than those in real-world agriculture because farmers are not always able to fully replicate recommended management practices (Eva-Marie *et al*.2019). If yield differences between experimental stations and farmers' fields would be the same for organic and conventional agriculture, yield comparisons between the two systems would not be systematically biased. However, there is increasing evidence that yield differences between experimental stations and farmers' fields are larger for organic than for conventional practices (Kravchenko *et al*. 2017). The reason is that organic farming is more knowledge intensive, and yields depend more on timely management interventions (Seufert *et al*. 2012 and Taheri *et al.* 2017). Hence, while the reported yield differences between organic and conventional agriculture may be true under experimental conditions, they may possibly underestimate the yield gaps that occur in real-world farming situations (Eva-Marie *et al*. 2019).

To test the external validity of results obtained from studies on experimental stations, Kniss *et al.* (2016) compared data from a large number of commercial farms in the United States. For cereals, they found yields on organic farms to be approximately 20% lower than on conven-

Vol.9, No3, pp.35-61, 2021

Print ISSN: 2053-5805(Print),

Online ISSN: 2053-5813(Online)

tional farms, which is similar to the yield gaps reported in the meta-analyses (Table 2). However, for certain vegetables, Kniss *et al.* (2016) reported yield gaps of 50% and more, which is significantly higher than what the meta-analyses reported. Under practical conditions in some parts of Europe, Pimentel et al. (2005) reported organic cereal yields to be 50% lower than conventional yields. These results should not be extrapolated, as unbiased evidence about organic yield effects under real-world conditions is limited (Kravchenko *et al*. 2017 and Leifeld 2016). In any case, given the higher knowledge requirements for successful organic farming, it is likely that the average yield gaps would rise if an increasing number of farmers would adopt organic practices. Another interesting question is how yield gaps between organic and conventional agriculture may further develop in the long run, when factoring in technological change. Available studies do not provide a clear answer to this question (Seufert and Ramankutty 2017).

As mentioned, yield gaps tend to increase with increasing conventional yields. In addition, over the coming decades yield gaps may potentially widen due to slower plant genetic improvements in organic farming. Organic standards ban the use of GMOs and genome editing techniques, which have significant potential to further increase crop yields and yield stability (Qaim 2016). On the other hand, organic agriculture has received limited research until now (Niggli 2015).

Nutrition and Health Effects of Organic Foods

Consumers often perceive organic foods to be more nutritious and healthier than conventional foods (Seufert *et al*. 2017). In principle, this could be due to lower contamination of organic foods with unhealthy components or higher contents of nutritionally desirable ingredients. A large body of literature has analyzed whether there are indeed significant differences between organic and conventional foods in terms of chemical composition (Eva-Marie *et al*. 2019).

Several systematic reviews suggest that organic food contains lower levels of chemical pesticide residues (Baranski *et al*. 2014, Dangour *et al*. 2010 and Huber *et al.* 2011). Whether this difference is relevant for human health depends on the types and quantities of pesticides used in conventional farming. In developed countries, where pesticide regulations are relatively strict, differences in risk for exceeding maximum allowed limits are generally negligible (Magkos et al. 2006 and Smith Spangler *et al*. 2012). In terms of other unhealthy components, some reviews conclude that organic foods contain lower concentrations of nitrate and cadmium (Baranski *et al.* 2014 and Huber *et al.* 2011). No significant difference was found in terms of fungal or bacterial contamination in most studies, although some suggest higher microbial concentrations in certain organic products such as fruits (Mditshwa *et al.* 2017).

Regarding nutritionally desirable components, most reviews suggest that organic plant products contain moderately higher concentrations of secondary metabolites such as phenolics (Baranski ´ et al. 2014, Brandt et al. 2011, Smith-Spangler et al. 2012). Concerning vitamin C and carotenoids, the results are mixed (Baranski et al. 2014, Hunter et al. 2011, Smith-Spangler et al. 2012). Higher levels of omega-3 fatty acids were found in organic milk and chicken (Baranski et al. 2017, Huber et al. 2011, Smith-Spangler et al. 2012). On the other hand, slightly lower concentrations of proteins and amino acids were found in organic foods (Baranski et al. 2014). However, it is not clear whether these differences in nutritionally desirable components between organic and conventional foods are clinically relevant (Baranski *et al*. 2017, Dangour *et al*. 2010, Forman and Silverstein 2012 and Smith-Spangler *et al.* 2012).

Certain differences in the composition of organic and conventional foods may not be surprising, as farming practices can affect plant chemistry (Brandt *et al.* 2011). Lower cadmium and nitrate levels in organic plants are linked to synthetic fertilizers not being allowed in organic farming (Baranski *et al.* 2014). Nitrogen fertilization promotes vegetative growth (associated with the ´ formation of proteins and carbohydrates) while limiting generative growth (associated with the formation of secondary metabolites) (Huber *et al*. 2011). Regarding animal products, higher levels of omega-3 fatty acids are potentially linked to outdoor grazing and larger biodiversity in pastures on organic farms. However, plant chemistry depends not only on the production system but also on weather conditions, soil type, genotype (variety), ripening stage of the product at harvest, and postharvest conditions (Brandt *et al*. 2011 and Huber *et al.* 2011). For instance, cadmium levels are highly dependent on soil type and may therefore also be high in organic products (Baranski *et al*. 2014). ´ Furthermore, management practices within both organic and conventional systems can vary (Huber *et al.* 2011 and Smith-Spangler *et al*. 2012). Organic cattle are not necessarily kept on biodiversity pastures, and conventional cattle are not always raised indoors with silage. As a result, the variation in the composition of foods can be larger within organic and conventional systems than between the two systems (Brandt *et al*. 2011).

A few studies suggest that the consumption of organic foods can be associated with a lower risk of allergies and eczema in infants (Alfven *et al.* 2006 and Kummeling *et al*. 2008). A cohort study carried out in France showed ´ that regular consumption of organic food is associated with lower rates of obesity (Kesse-Guyot *et al*. 2013). However, a systematic review did not find differences in health outcomes (Dangour *et al*. 2010). Generally, it is difficult to prove causality with observational data. Organic consumers are known to make different—often healthier—food and lifestyle choices (Huber *et al.* 2011 and Kesse-Guyot *et al*. 2013), which can lead to selection bias in impact evaluation. Given the limited evidence, general conclusions about health effects of organic food consumption cannot be drawn (Baranski *et al*. 2017, Dangour *et al*. 2010, Forman and Silverstein 2012).

Food Production Quantities

As discussed, average crop yields are lower in organic than in conventional agriculture. Consequently, total conversion to organic practices would require more land to produce the same quantity of food. At the beginning discussed the average organic yield gaps of 19–25%, which would mean additional land requirements of 23–33%. But we also discussed that yield gaps could increase if more farmers adopted organic agriculture. Organic farming is more

Print ISSN: 2053-5805(Print),

Online ISSN: 2053-5813(Online)

knowledge intensive than conventional farming; therefore, there is little reason to assume that organic yields obtained on experimental stations or on 1% of the agricultural area could be extrapolated to all agricultural land worldwide. Larger yield gaps are especially likely when it comes to up scaling organic agriculture in the developing-country small farm sector, where levels of formal education are often low, and access to agricultural training is limited. Average yield gaps of 30–40% would already mean that 43–67% of additional land would be required to produce the same quantity of food with organic practices, implying a significant loss of natural habitats. (Eva-Marie *et al*. 2019) Another relevant question is whether sufficient nutrients from organic matter would be available if all of the world's agriculture were converted to organic practices (Tomich *et al*. 2011). Today, organic agriculture often relies on nutrient inputs from conventional farms and heavily depends on the livestock sector (Nowak *et al*. 2013). But would there be enough animal manure available to supply nutrients to a much larger area under organic production? Currently only about 11% of the nitrogen inputs to global crop production come from animal manure, and another 8% are from crop residues (Seufert and Ramankutty 2017). Completely replacing synthetic fertilizers, which are banned in organic farming, would mean significantly increasing the number of farm animals kept. Given the climate effects of animal husbandry and the additional land required for fodder production, this would hardly be a sustainable scenario. Alternatively, more leguminous cover crops could be grown to restore nitrogen in the soil. However, providing sufficient nitrogen would require a legume cover crop on each field every year, which would not be possible without reducing the area available for food production (Connor 2008). Providing insufficient nutrients would mean additional yield gaps. In summary, providing sufficient food for the growing world population through organic farming alone might be possible but not without taking significantly more land into production. (Eva-Marie *et al*. 2019).

The expansion of agricultural land is a major contributor to biodiversity loss and climate change (Foley *et al*. 2011 and Green *et al*. 2005). As discussed in Section 5, the biodiversity gains from organic production cannot offset the biodiversity losses associated with additional land-use change. In other words, complete conversion to organic agriculture would likely be associated with additional GHG emissions and a net loss in biodiversity. (Eva-Marie *et al*. 2019)

Sustainable Consumption

When calculating the food quantities that have to be produced to feed the world population, current patterns and trends of food consumption are typically assumed. However, a significant share of the food produced is lost or wasted along the value chain, including foods thrown away by the end-consumer (FAO 2011). Moreover, the high consumption of meat and dairy products in many parts of the world is associated with considerable resource inefficiencies. In other words, much less food production would be required if food losses and waste were reduced and if all people became vegetarians or vegans. Such a scenario could certainly change the conclusions about the potential of organic agriculture to feed the world. Indeed, in recent simulations, Erb *et al.* (2016) and Muller *et al*. (2017) showed that the predicted world population in 2050 could be fed even with lower yields and without the loss of additional natural habitat if only vegan diets were consumed. However, completely vegetarian or vegan diets are not realistic and also not desirable from a nutritional perspective (Seves *et al*. 2017 and White and Hall 2017).

Nor do vegetarian or vegan diets fit together with increased organic production, as organic practices depend on the availability of animal manure. But with or without organic agriculture, changes in people's consumption habits toward less resource-intensive diets will have to be an important part of sustainable development strategies (Foley *et al.* 2011). Especially in rich countries, this should also involve less consumption of animal products. In several countries in Europe, the per capita consumption of meat is actually decreasing, but the decrease is slow. Behavioral change processes are not easy to instigate and accelerate through political measures, and the global trend goes in the opposite direction. Especially in Asia and Africa, the demand for animal products is rapidly rising, and the situation is similar in terms of food losses and waste. Although reductions are desirable, a zero waste scenario is hardly realistic in the foreseeable future. (Eva-Marie *et al*. 2019)

Food Prices and Food Security

Mainly owing to lower average yields, organic production is associated with higher costs per unit of output and thus higher prices. Currently, the higher prices only apply to the small certified organic market segment, but total conversion to organic agriculture would mean significantly higher food prices in the entire market. In developed countries, most consumers are sufficiently rich so that higher food prices would not jeopardize their food security. But in developing countries, the situation is different. Many poor households spend over 50% of their income on food. In such situations, food price increases are associated with higher levels of food insecurity and under nutrition, especially in urban areas (Ecker and Qaim 2011).

Socio economic Implications For Organic Farmers

Organic farming can only contribute to sustainable agricultural development when it is economically viable for farmers, meaning that the income derived from organic production is at least as high as that from conventional farming. A recent meta-analysis has analyzed this issue and includes studies from 14 different countries (Crowder and Reganold 2015). Results show that organic farming is 22–35% more profitable than conventional agriculture on average. While organic yields are significantly lower, organic farmers receive higher prices for their products in certified organic markets. Average price premiums at the farm level are on the magnitude of 30%. Without price premiums, organic farming would be less profitable than conventional farming (Crowder and Reganold 2015). Whereas the meta-analysis by Crowder and Reganold (2015) includes data from different parts of the world, most of the original studies refer to the United States and other developed countries. Only a few of the studies refer to developing countries, and no single study looked at the situation in Africa. In terms of absolute numbers, most organic producers are smallholder farmers in developing countries. Moreover, smallholder farmers comprise a large share of the world's poor and hungry people (FAO 2014 and FAO and Qaim, 2012). Hence, a better understanding of what organic farming can mean economically for farmers in developing countries is important (Jouzi *et al.* 2017).

Smallholder Farmers and Organic Yields

As discussed in past Section, yields obtained with organic production methods tend to be lower than those in conventional agriculture. However, yield differences depend on the particular context. In situations where most farmers have limited access to modern production technologies and apply low quantities of purchased inputs anyway, organic yields can be similar to conventional ones (Beuchelt and Zeller 2011, Jena *et al*. 2017, Kramol *et al.* 2013, Parvathi and Waibel 2016). This is not an untypical situation of smallholders in developing countries, especially in Africa. With intensive training and a substantial increase in the use of organic fertilizers, organic yields can even be significantly higher than those obtained from low-input conventional farming (Bolwig *et al.* 2009, Ibanez and Blackman 2016, Wollni and Andersson 2014). Employing organic soil management practices can also reduce yield variability and vulnerability to drought and other weather extremes (Niggli 2015, Scialabba and Muller-Lindenlauf 2010). However, where modern inputs are available and more commonly used, organic farmers typically have lower yields than conventional farmers. Yield gaps tend to increase during the process of economic development (Valkila 2009).

Price Premiums

Most organic farmers in developing countries produce cash crops (e.g, coffee, tea, cocoa, tropical fruits) for export to rich countries, where consumers pay a significant price premium for certified organic products (Raynolds 2004, Willer and Lernoud 2017). However, the price premium at the retail level is not necessarily reflected in the price that farmers receive for their organic produce because various actors along the value chain also capture some of the benefits (Minten *et al*. 2018). In some cases, prices received by organic farmers in developing countries are not higher than those in conventional markets (Chiputwa *et al.* 2015, Parvathi and Waibel 2016). Nevertheless, most studies find that organic premiums at the farmer level range between 6% and 44% (Beuchelt and Zeller 2011, Bolwig *et al*. 2009, Ibanez and Blackman 2016, Jena *et al.* 2017, Jones and Gibbon 2011, Kleemann *et al.* 2014, Mitiku *et al*. 2017 and Valkila 2009).

However, oftentimes organic smallholders do not sell all of their harvest in certified markets (Jena *et al.* 2012, 2017; Kleemann *et al*. 2014). There are several reasons why they may decide to sell some or all of their crops in conventional markets. First, sometimes the quality requirements of certified markets cannot be met (Bolwig *et al.* 2009 and Weber 2011). Second, there can be situations when the farmer organizations lack the capacity to handle the large supply of certified crops delivered by their members (Jena *et al.* 2012, Snider *et al.* 2017). Third, price premiums vary and can be small during certain periods (Snider et al. 2017). Finally, even when price premiums are more significant, selling in certified markets is often associated with payment delays. When facing urgent cash needs, organic farmers sell to local traders at lower prices but in return for immediate cash (Bacon 2005, Beuchelt and Zeller 2011, Valkila 2009).

@ECRTD-UK https://www.eajournals.org/ https://doi.org/10.37745/gjar.2013

Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Given these conditions and constraints, the average price that organic smallholders receive may be lower than what the reported price premiums may suggest. (Eva-Marie *et al*. 2019).

Production Costs

In the small farm sector, certification fees and related administrative costs are typically covered by farmer cooperatives, exporters, or development organizations. However, meeting certification requirements is often associated with certain investment costs (e.g, new equipment) that farmers have to bear individually (Kleemann *et al.* 2014). Also, organic certification involves a three-year transition period, which can be understood as a sunk cost. During this transition period, farmers cannot yet benefit from an organic price premium, but yields are often particularly low due to learning and experimentation with the new production methods (Caldwell *et al.* 2014, Ruben and Fort 2012, Weber 2011).

Organic certification can also influence variable production costs. Although costs for chemical inputs are saved, maintaining and increasing yields requires large quantities of organic material (e.g, manure). The organic matter available at the farm itself may not suffice, so that additional material has to be purchased (de Ponti *et al.* 2012). The cost can be substantial, especially when local market supply of organic matter is limited (Jena *et al*. 2017, Kloos and Renaud 2014). Furthermore, organic farming is typically more labor intensive, as manual labor is needed for weeding, application of organic fertilizers, and other operations (Valkila 2009). Consequently, households have to hire additional labor or use more family labor (Beuchelt and Zeller 2011, Kleemann *et al*. 2014, Ruben and Fort 2012).

Indirect Economic Benefits

In addition to possible price premiums, organic certification may also be associated with indirect economic benefits. In developing countries, certified farmer organizations (or buyers) usually offer services, such as price information, training, credit, or value addition, to help farmers meet certification requirements and produce the quality demanded in international organic markets (Bolwig *et al.* 2009, Jones and Gibbon 2011). As smallholder access to rural services is generally low, such initiatives by certified organizations can improve the situation more broadly and result in income gains (Mitiku *et al.* 2017, Parvathi and Waibel 2016). However, the range and quality of services to be provided is not specified in organic standards, so the relevance of such indirect benefits varies (Jena *et al.*2012 and Meemken *et al.*2017a). Collective marketing or contractual arrangements are also commonplace in smallholder organic value chains. Such arrangements can be beneficial for farmers irrespective of organic certification(Bellemare 2012, Fischer and Qaim 2012).

Overall Profitability and Income

The previous subsections showed that yields, prices, and production costs in organic farming are highly context specific. As a result, studies come to different conclusions regarding the overall profitability of organic certification. Some studies find that the price premium is insufficient to compensate for lower yields and/or higher production costs (Barham and Weber 2012,

@ECRTD-UK https://www.eajournals.org/ https://doi.org/10.37745/gjar.2013

Ibanez and Blackman 2016, Mitiku *et al*. 2017). Other studies suggest that organic certification contributes to higher profitability in the small farm sector (Bolwig *et al.* 2009, Kleemann and Abdulai 2013, Kleemann *et al*. 2014).

We conclude that the profit effects of organic farming are less clear cut in developing countries than what the global meta-analysis of Crowder and Reganold (2015) suggests. However, a narrow focus on the profits from one certified crop alone may yield an incomplete picture of the overall economic impacts of organic farming. This is especially true in the small farm sector, where households usually engage in multiple farm and off-farm activities. For instance, when households decide to allocate land, labor, and capital to organic production, the income from other economic activities may also be affected through resource reallocation and other types of spillovers. Several studies have analyzed the effects of organic certification on total household income, thus implicitly capturing spillovers. Again, the results are mixed and context specific. While some studies suggest that organic certification has no effect or even negative effects on income and the likelihood to be poor (Barham and Weber 2012, Beuchelt and Zeller 2011, Chiputwa *et al.* 2015, Jena *et al.* 2017, Mitiku *et al.* 2017, Valkila 2009), others find exactly the opposite (Ayuya *et al*. 2015, Jones and Gibbon 2011, Kleemann and Abdulai 2013).

Broader Social Development Goals

Unlike other sustainability standards, such as Fair-trade, most organic standards do not include specific certification requirements related to social issues, such as child labor or gender equality (Meemken and Qaim 2018, Seufert *et al*. 2017). Nevertheless, studies suggest that organic certification can affect social outcomes in positive and negative ways. If it improves income, organic certification may enable households to make beneficial investments in human capital formation. For instance, Gitter *et al.* (2012) show that double organic-Fair trade certification has a positive effect on child education in Mexico. Such investments in better child education are unlikely to occur in the absence of income gains, as Meemken *et al.* (2017a) show with data from organic coffee producers in Uganda. Several studies have also analyzed nutrition effects, suggesting that organic certification helps to improve food security and dietary quality in farming households (Becchetti *et al.* 2012, Chiputwa and Qaim 2016, Meemken *et al.* 2017a).

Positive effects on dietary diversity can even occur in the absence of income gains (Meemken *et al.* 2017a). One reason is greater production diversity on organic farms, which is known to affect household dietary diversity through the subsistence pathway (Sibhatu *et al.* 2015). Organic farming can also reduce occupational health hazards, as farmers and farm workers are less exposed to chemical pesticides (Asfaw *et al.* 2010, Forman and Silverstein 2012, Shreck *et al*. 2006). The ban of chemical pesticides can also have interesting gender implications. On the one hand, pesticide bans can increase women's workload, as women are often heavily involved in labor-intensive activities such as weeding (Bolwig 2012, Lyon *et al.* 2010). On the other hand, pesticide-free production can promote women's participation in cash cropping

(Kloos and Renaud 2014). The reason is that the handling of pesticides is primarily considered a male task in many parts of Africa and Asia. More generally, organic certification can have effects on labor markets and employment conditions in the farming sector and also further downstream (Taheri *et al*. 2017). Such effects are not yet sufficiently understood.

CONCLUSION

Many rich-country consumers consider organic foods to be healthier and organic agriculture to be more environmentally friendly than conventional farming methods. These perceived benefits are influencing food and agricultural policies. Sometimes organic farming is promoted as the paradigm for sustainable agriculture and food security. In this article, we have reviewed the available literature about the economic, social, environmental, and health effects of organic agriculture from a global to local perspective. Although some studies show differences between the chemical composition of organic and conventional foods, In terms of environmental and climate effects, organic farming is less polluting than conventional farming when the effects are measured per unit of land but not when measured per unit of output. As the demand for food and agricultural products is high and growing, expressing environmental and climate effects per unit of output seems more relevant from a global point of view.

The reason why organic farming is more environmentally friendly than conventional farming per unit of land but not per unit of output is the lower average yield obtained with organic agriculture. Currently observed yield gaps between organic and conventional methods might further increase if a larger number of farmers would switch to organic practices. This is especially true in developing countries, where smallholder farmers tend to have relatively low levels of education and limited access to agricultural training. Expanding agricultural production further into natural habitats would lead to additional GHG emissions and loss in biodiversity. Depending on the context, such indirect land-use change effects could outweigh the positive environmental effects of organic farming per unit of land.

There is a need to encourage the research on organic farming and try to evaluate the potential of different organic production. So far only fewer efforts have been made using organic production. Continued research would help to strengthen this review, especially if the scope was expanded to the south west Ethiopia as a whole .More intense research in this direction is essential in the development of organic farming. Also, more efforts need to be done by agriculturists, scientists, NGOs and government to work together for successively this through organic farming and eco-friendly approaches.

Referance

Alfven, T., Braun-Fahrl ´ ander, C., Brunekreef, B., von Mutius, E., Riedler, J., et al. 2006. Allergic diseases and atopic sensitization in children related to farming and anthropomorphic life style The Parsifal Study. Allergy 61, 414–421.

Asfaw, S., Mithofer, D., Waibel, H., 2010.Agrifood supply chain, private-sector standards, and farmers' health: evidence from Kenya. Agric. Econ. 41, 251–63

Ayuya, O.I., Gido, E.O., Bett, H.K., Lagat, J.K., Kahi, A.K., Bauer, S., 2015. Effect of certified organic production systems on poverty among smallholder farmers: empirical evidence from Kenya. World Dev. 67, 27–37

Bacon, C., 2005. Confronting the coffee crisis: Can Fair Trade, organic, and specialty coffees reduce small-scale farmer vulnerability in northern Nicaragua? World Dev.33, 497–511

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M.J., et al. 2007. Organic agriculture and the global food supply. Renew. Agric. Food Syst. 22:86–108

Baranski, M., Rempelos, L., Iversen, P.O., Leifert, C., 2017. Effects of organic food consumption on human health; ´ the jury is still out! Food Nutr. Res. 61, 1287333

Baranski, M., Srednicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., et al. 2014. Higher anti oxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses.Br. J. Nutr. 112, 794–811

Barham, B.L., Weber, J.G., 2012. The economic sustainability of certified coffee: recent evidence from Mexico and Peru. World Dev. 40, 1269–79

Becchetti, L., Conzo, P., Gianfreda, G., 2012. Market access, organic farming and productivity: the effects of Fair Trade affiliation on Thai farmer producer groups. Aust. J. Agric. Resource. Econ 56, 117–40

Bellemare, M.F., 2012. As you sow, so shall you reap the welfare impacts of contract farming World Dev. 40, 1418–34

Bengtsson, J., Ahnstrom, J., Weibull, A.C., 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. J. Appl. Ecol. 42, 261–69

Berry, P.M., Sylvester-Bradley, R., Philipps, L., Hatch, D.J., Cattle, S.P., et al. 2002. Is the productivity of organic farms restricted by the supply of available nitrogen? Soil Use Manag. 18, 248–55

Beuchelt, T.D., Zeller, M., 2011. Profits and poverty: certification's troubled link for Nicaragua's organic and fair trade coffee producers. Ecol. Econ. 70, 1316–24

Bolwig, S., 2012. Poverty and gender effects of smallholder organic contract farming in Uganda USSP Work. Pap. 8, Int. Food Policy Res. Inst., Washington, DC

Bolwig, S., Gibbon, P., Jones, S., 2009. The economics of smallholder organic contract farming in tropical Africa. World Dev. 37, 1094–104

Brandt, K., Leifert, C., Sanderson, R., Seal, C.J., 2011. Agro ecosystem management and nutritional quality of plant foods: the case of organic fruits and vegetables. Crit. Rev. Plant Sci.30, 177-97

Brenes-Munoz, T., Lakner, S., Brummer, B., 2016. What influences the growth of organic farms? Evidence from ¨ a panel of organic farms in Germany. Ger. J. Agric. Econ. 65, 1–15

Caldwell, B., Mohler, C.L., Ketterings, Q.M., Di Tommaso, A., 2014. Yields and profitability during and after transition in organic grain cropping systems. Agron. J. 106, 871–80

Vol.9, No3, pp.35-61, 2021

Print ISSN: 2053-5805(Print),

Online ISSN: 2053-5813(Online)

Carlson, A., Jaenicke, E., 2016. Changes in retail organic price premiums from 2004 to 2010 Econ. Res. Rep. 209, US Dep. Agric., Washington, DC

Cassman, K., 2007. Editorial response by Kenneth Cassman: Can organic agriculture feed them world science to the rescue? Renew. Agric. Food Syst. 22, 83–84

Chiputwa, B., Qaim, M., 2016. Sustainability standards, gender, and nutrition among smallholder farmers in Uganda. J. Dev. Stud. 52, 1241–57

Chiputwa, B., Spielman, D.J., Qaim, M., 2015. Food standards, certification, and poverty among

Clark M, Tilman D. 2017.Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. Environ. Res. Lett. 12, 64016 Connor DJ. 2008. Organic agriculture cannot feed the world. Field Crops Res. 106, 187–90

Connor, D.J., Mınguez, M.I., 2012. Evolution not revolution of farming systems will best feed and green the world. Glob. Food Secure. 1, 106–13

Crowder, D.W., Northfield, T.D., Strand, M.R., Snyder, W.E., 2010. Organic agriculture promotes evenness and natural pest control. Nature 466, 109–12

Crowder, D.W., Reganold, J.P., 2015. Financial competitiveness of organic agriculture on a global scale. PNAS 112, 7611–16

Dangour, A.D., Lock, K., Hayter, A., Aikenhead, A., Allen, E., Uauy, R., 2010. Nutrition-related health effects of organic foods: a systematic review. Am. J. Clin. Nutr. 92, 203–10

De Ponti, T., Rijk, B., vanIttersum, M.K., 2012. The crop yield gap between organic and conventional agriculture. Agric. Syst. 108, 1–9

Ecker, O., Qaim, M., 2011. Analyzing nutritional impacts of policies: an empirical study for Malawi. World Dev. 39, 412–28

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Kadner, S., Minx, J.C., et al. 2014. Technical summary In Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,

Ed. O Edenhofer, R Pichs-Madruga, Y Sokona, E Farahani, S Kadner, et al., pp. 31–107. Cam bridge, UK/New York: Cambridge Univ. Press Erb KH, Lauk C, Kastner T, Mayer A, Theurl.MC, Haberl H. 2016. Exploring the biophysical option space for feeding the world without deforestation. Nat. Commun.7:11382

Eva-Marie, M., Matin, Q., 2019 Annu. Rev. Resour. Econ. Organic Agriculture, FoodSecurity, and the Environment 2018. 10, 39–63

Evenson, R.E., Gollin, D., 2003.Assessing the impact of the green revolution, 1960–2000.Science 300, 758–62

FAO (Food Agric. Organ), 2011. Global Food Losses and Food Waste: Extent, Causes, and Prevention. Rome:

FAO (Food Agric. Organ), 2014. The State of Food and Agriculture: Innovation in Family Farming. Rome:

FAO (Food Agric. Organ), 2017.The State of Food Security and Nutrition in the World. Rome:

FAO, Fischer, E., Qaim, M., 2012. Gender, agricultural commercialization, and collective action in Kenya. Food Secur. 4, 441–53

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., et al. 2011.Solutions for a cultivated planet. Nature 478:337–42

Forman, J., Silverstein, J., 2012. Organic foods: health and environmental advantages and disad vantages. Pediatrics 130, e1406–15

Forster, D., Andres, C., Verma, R., Zundel, C., Messmer, M.M., Mader, P., 2013. Yield and economic performance of organic and conventional cotton-based farming systems results from a field trial in India. PLOS ONE 8:e81039

Funk, C., Kennedy, B., 2016. The New Food Fights: US Public Divides over Food Science Washington, DC: Pew Res. Cent. Gabriel D, Sait SM, Kunin WE, Benton TG, Steffan Dewenter I. 2013.

Food production versus biodiversity: comparing organic and conventional agriculture. J. Appl Ecol. 50:355–64

Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., et al. 2012. Enhanced top soil carbon stocks under organic farming. PNAS 109:18226–31

Gitter, S.R., Weber, J.G., Barham, B.L., Callenes, M., Valentine, J.L., 2012. Fair Trade-organic coffee cooperatives, migration, and secondary schooling in southern Mexico. J. Dev. Stud. 48, 445–63

Godfray, H.C.J., Beddington, J.R., Crite, I.R., Haddad, L., Lawrence, D., et al. 2010. Food security: the challenge of feeding 9 billion people. Science 327:812–18

Gomiero, T., Paoletti, M.G., Pimentel, D., 2008. Energy and environmental issues in organic and conventional agriculture. Crit. Rev. Plant Sci. 27, 239–54

Gomiero, T., Pimentel, D., Paoletti, M.G., 2011. Environmental impact of different agricultural management practices: conventional versus organic agriculture. Crit. Rev. Plant Sci.30, 95-124

Goulding, K.W.T., Trewavas, A.J., 2009. Can organic agriculture feed the world? Spec. Pap, Ag Bioorld, Tuskegee, AL. caseiddarchive& newsid=2894

Green, R.E., Cornell, S.J., Scharlemann, J.P.W., Balmford, A., 2005. Farming and the fate of wild nature. Science 307, 550–55

Greenpeace, 2015. Fostering economic resilience: the financial benefits of ecological farming in Kenya and Malawi. Rep, Greenpeace, Johannesbg. africa/Global/africa/graphics/ Food For life/ Fostering %20 Economic %20 Resilience.pdf

Halberg, N., 2012. Assessment of the environmental sustainability of organic farming: definitions, indicators and the major challenges. Can. J. Plant Sci. 92, 981–96

Hertel, T.W., 2015. The challenges of sustainably feeding a growing planet. Food Secur. 7, 185-98

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V., Evans, A.D., 2005. Does organic farming benefit biodiversity? Biol. Conserv. 122, 113–30

Huber, M., Rembiał kowska, E., Srednicka, D., Bugel, S., van de Vijver, L., 2011. Organic food and impact on human health: assessing the status quo and prospects of research. Wagening. J Life Sci. 58(3–4), 103–9

Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Hunter, D., Foster, M., McArthur, J.O., Ojha, R., Petocz, P., Samman, S., 2011. Evaluation of the micro nutrient composition of plant foods produced by organic and conventional agricultural methods. Crit. Rev. Food Sci. Nutr. 51, 571–82

Ibanez, M., Blackman, A., 2016. Is eco-certification a win-win for developing country agriculture? Organic coffee certification in Colombia. World Dev. 82, 14–27

Jena, P.R., Chichaibelu, B.B., Stell macher, T., Grote, U., 2012. The impact of coffee certification on small-scale producers' livelihoods: a case study from the Jimma Zone, Ethiopia. Agric Econ. 43, 429–40

Jena, P.R., Stell macher, T., Grote, U., 2017. Can coffee certification schemes increase incomes of smallholder farmers? Evidence from Jinotega, Nicaragua. Environ. Dev. Sustain. 19, 45–66

Jones, S., Gibbon, P., 2011. Developing agricultural markets in Sub-Saharan Africa: organic cocoa in rural Uganda. J. Dev. Stud. 47, 1595–618

Jouzi, Z., Azadi, H., Taheri, F., Zarafshami, K., Gebrehiwot, K., et al. 2017. Organic farming and small-scale farmers: main opportunities and challenges. Ecol. Econ. 132, 144–154

Kallas, Z., Serra, T., Gil, J.M., 2010. Farmers objectives as determinants of organic farming adoption: the case of Catalonian vineyard production. Agric. Econ. 41, 409–23

Kesse- Guyot, E., Peneau, S., Mejean, C., Szabo de Edelenyi, F., Galan, P., et al. 2013. Profiles of organic food consumers in a large sample of French adults: results from the Nutrient-Sante cohort study. PLOS ONE 8:e76998

Kleemann, L., Abdulai, A., 2013. Organic certification, agro-ecological practices and return on investment: evidence from pineapple producers in Ghana. Ecol. Econ. 93, 330–41

Kleemann, L., Abdulai, A., Buss, M., 2014. Certification and access to export markets: adoption and return on investment of organic-certified pineapple farming in Ghana. World Dev. 64, 79–92

Kloos, J., Renaud, F.G., 2014. Organic cotton production as an adaptation option in north-west Benin. Outlook Agric. 43, 91–100

Klumper, W., Kathage, J., Qaim, M., 2013. Perception of global food security issues in the German public. Ber. Land wirtsch. 91, 14

Kniss, A.R., Savage, S.D., Jabbour, R., 2016. Commercial crop yields reveal strengths and weaknesses of organic agriculture in the United States. PLOS ONE 11:e0161673

Kramol, P., Villano, R., Kristiansen, P., Fleming, E., 2013. Productivity differences between organic and other vegetable farming systems in northern Thailand. Renew. Agric. Food Syst. 30, 154–69

Kravchenko, A.N., Snapp, S.S., Robertson, G.P., 2017. Field-scale experiments reveal persistent yield gaps in low-input and organic cropping systems. PNAS 114, 926–31

Kuminoff, N.V., Wossink, A., 2010. Why isn't more US farmland organic? J. Agric. Econ. 61, 240–58

Kummeling, I., Thijs, C., Huber, M., van de Vijver, L.P.L., Snijders, B.E.P., et al. 2008. Consumption of organic foods and risk of atopic disease during the first 2 years of life in the Netherlands. Br. J. Nutr. 99, 598–605

Lapple, D., 2010. Adoption and abandonment of organic farming: an empirical investigation of the Irish drystock sector. J. Agric. Econ. 61, 697–714

Lee, K.S., Choe, Y.C., Park, S.H., 2015. Measuring the environmental effects of organic farming: a meta-analysis of structural variables in empirical research. J. Environ. Manag. 162, 263–74

Leifeld, J., 2016. Current approaches neglect possible agricultural cutback under large-scale organic farming. A comment to Ponisio et al. Proc. R. Soc. B 283, 20151623

Lockeretz, W., 2007. What explains the rise of organic farming? In Organic Farming: An International History, ed. W Lockeretz, 1–8.

Lotter, D., 2015. Facing food insecurity in Africa: why, after 30 years of work in organic agriculture, I am promoting the use of synthetic fertilizers and herbicides in small-scale staple crop production. Agric. Hum. Values 32, 111–18

Lynch, D.H., Mac Rae, R., Martin, R.C., 2011. The carbon and global warming potential impacts of organic farming: Does it have a significant role in an energy constrained world? Sustainability 3, 322–62

Lyon, S., Bezaury, J.A., Mutersbaugh, T., 2010. Gender equity in fair trade–organic coffee producer organizations: cases from Mesoamerica. Geoforum 41, 93–103

Mader, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P., Niggli, U., 2002. Soil fertility and biodiversity in organic farming. Science 296, 1694–97

Magkos, F., Fotini, A., Zampelas, A., 2006. Organic food: buying more safety or just peace of mind? A critical review of the literature. Crit. Rev. Food Sci. Nutr. 46, 23–56

Mditshwa, A., Magwaza, L.S., Tesfay, S.Z., Mbili, N., 2017. Postharvest quality and composition of organically and conventionally produced fruits: a review. Sci. Hortic. 216, 148–159

Meemken, E.M., Qaim, M., 2018. Can private food standards promote gender equality in the small farm sector? J. Rural Stud. 58, 39–51

Meemken, E.M., Spielman, D.J., Qaim, M., 2017a. Trading off nutrition and education? A panel data analysis of the dissimilar welfare effects of organic and fair trade standards. Food Policy 71, 74–85

Meemken, E.M., Veettil, P.C., Qaim, M., 2017b. Towards improving the design of sustainability standards a gendered analysis of farmers' preferences. World Dev. 99, 285–98

Meier, M.S., Stoessel, F., Jungbluth, N., Juraske, R., Schader, C., Stolze, M., 2015. Environmental impacts of organic and conventional agricultural products—are the differences captured by life cycle assessment? J. Environ. Manag. 149, 193–208

Mercati, V., 2016. Organic agriculture as a paradigm of sustainability: Italian food and its progression in the global market. Agric. Sci. Proc. 8, 798–802

Minten, B., Dereje, M., Engeda, E., Tamru, S., 2018. Tracking the quality premium of certified coffee: evidence from Ethiopia. World Dev. 101, 119–32

Mitiku, F., de Mey, Y., Nyssen, J., Maertens, M., 2017. Do private sustainability standards contribute to income growth and poverty alleviation? A comparison of different coffee certification schemes in Ethiopia. Sustainability 9, 246

Vol.9, No3, pp.35-61, 2021

Print ISSN: 2053-5805(Print),

Online ISSN: 2053-5813(Online)

Mondelaers, K., Aertsens, J., van Huylen broeck, G., 2009. A meta-analysis of the differences in environmental impacts between organic and conventional farming. Br. Food J. 111, 1098–119

Muller, A., Schader, C., Scialabba, N.E.L., Bruggemann, J., Isensee, A., et al. 2017. Strategies for feeding the world ¨ more sustainably with organic agriculture. Nat. Commun. 8:1290

Niggli, U., 2015. Sustainability of organic food production: challenges and innovations. Proc. Nutr. Soc. 74, 83–88

Nowak, B., Nesme, T., David, C., Pellerin, S., 2013. To what extent does organic farming rely on nutrient inflows from conventional farming? Environ. Res. Lett. 8, 044045

Oehl, F., Oberson, A., Tagmann, H.U., Besson, J.M., Dubois, D., et al. 2002. Phosphorus budget and phosphorus availability in soils under organic and conventional farming. Nutr. Cycl. Agroecosyst. 62, 25–35

Parvathi, P., Waibel, H., 2016. Organic agriculture and fair trade: A happy marriage? A case study of certified smallholder black pepper farmers in India. World Dev. 77, 206–20

Phalan, B., Onial, M., Balmford, A., Green, R.E., 2011. Reconciling food production and biodiversity conservation: land sharing and land sparing compared. Science 333, 1289–91

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seide, R., 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. Bio Science 55, 573–82

Ponisio, C.P., M'Gonigle, L.K., Mace, K.C., Palomino, J., de Valpine, P., Kremen, C., 2015. Diversification practices reduce organic to conventional yield gap. Proc. R. Soc. B 282, 20141396

Probst, L., Houedjofonon, E., Ayerakwa, H.M., Haas, R., 2012. Will they buy it? The potential for marketing organic vegetables in the food vending sector to strengthen vegetable safety: a choice experiment study in three West African cities. Food Policy 37, 296–308

Qaim, M., 2016. Genetically Modified Crops and Agricultural Development. New York: Palgrave Macmillan

Qaim, M., 2017. Globalization of agrifood systems and sustainable nutrition. Proc. Nutr. Soc. 76, 12–21

Raynolds, L.T., 2004. The globalization of organic agro-food networks. World Dev. 32, 725–43

Reganold, J.P., Wachter, J.M., 2016. Organic agriculture in the twenty-first century. Nat. Plants 2, 15221

Ruben, R., Fort, R., 2012. The impact of Fair Trade certification for coffee farmers in Peru. World Dev. 40, 570–82

Schneider, M.K., Luscher, G., Jeanneret, P., Arndorfer, M., Ammari, Y., et al. 2014. Gains to species diversity in ¨ organically farmed fields are not propagated at the farm level. Nat. Commun. 5, 4151

Scialabba, N.E.H., Muller-Lindenlauf, M., 2010. Organic agriculture and climate change. ¨ Renew. Agric. Food Syst. 25, 158–69

Serra, T., Zilberman, D., Gil, J.M., 2008. Differential uncertainties and risk attitudes between conventional and organic producers: the case of Spanish arable crop farmers. Agric. Econ. 39, 219–29

Seufert, V., Ramankutty, N., 2017. Many shades of gray—the context-dependent performance of organic agriculture. Sci. Adv. 3:e1602638

Seufert, V., Ramankutty, N., Foley, J.A., 2012. Comparing the yields of organic and conventional agriculture. Nature 485, 229–32

Seufert, V., Ramankutty, N., Mayerhofer, T., 2017. What is this thing called organic?—How organic farming is codified in regulations. Food Policy 68, 10–20

Seves, S.M., Verkaik-Kloosterman, J., Biesbroek, S., Temme, E.H.M., 2017. Are more environmentally sustainable diets with less meat and dairy nutritionally adequate? Public Health Nutr. 20, 2050–62

Shreck, A., Getz, C., Feenstra, G., 2006. Social sustainability, farm labor, and organic agriculture: findings from an exploratory analysis. Agric. Hum. Values 23, 439–49

Sibhatu, K.T., Krishna, V.V., Qaim, M., 2015. Production diversity and dietary diversity in smallholder farm households. PNAS 112, 10657–62

Skinner, C., Gattinger, A., Muller, A., Mader, P., Fließbach, A., et al. 2014. Greenhouse gas fluxes from agricultural soils under organic and non-organic management—a global meta-analysis. Sci. Total Environ. 468–469:553–63

Smith, L.G., Williams, A.G., Pearce, B.D., 2015. The energy efficiency of organic agriculture: a review. Renew. Agric. Food Syst. 30, 280–301

Smith-Spangler, C., Brandeau, M.L., Hunter, G.E., Bavinger, J.C., Pearson, M., et al. 2012. Are organic foods safer or healthier than conventional alternatives? A systematic review. Ann. Intern. Med. 157:348–66

Snider, A., Gutierrez, I., Sibelet, N., Faure, G., 2017. Small farmer cooperatives and voluntary coffee certifications: ´ rewarding progressive farmers of engendering widespread change in Costa Rica? Food Policy 69, 231–42

Stolze, M., Lampkin, N., 2009. Policy for organic farming: rationale and concepts. Food Policy 34, 237–44

Taheri, F., Azadi, H., D'Haese, M., 2017. A world without hunger: Organic or GM crops? Sustainability 9, 580

Tomich, T.P., Brodt, S., Ferris, H., Galt, R., Horwath, W.R., et al. 2011. Agro ecology: a review from a global-change perspective. Annu. Rev. Environ. Resour. 36:193–222

Treu, H., Nordborg, M., Cederberg, C., Heuer, T., Claupein, E., et al. 2017. Carbon footprints and land use of conventional and organic diets in Germany. J. Clean. Prod. 161:127–42

Trewavas, A., 2001. Urban myths of organic farming. Nature 410, 409–10

Tuck, S.L., Winqvist, C., Mota, F., Ahnstrom, J., Turnbull, L.A., Bengtsson, J., 2014. Land-use intensity and the ¨ effects of organic farming on biodiversity: a hierarchical meta-analysis. J. Appl. Ecol. 51, 746–55

Tuomisto, H.L., Hodge, I.D., Riordan, P., Macdonald, D.W., 2012. Does organic farming reduce environmental impacts? A meta-analysis of European research. J. Environ. Manag. 112, 309–20

Valkila, J., 2009. Fair Trade organic coffee production in Nicaragua sustainable development or a poverty trap? Ecol. Econ. 68, 3018–25

Vogt, G., 2007. The origins of organic farming. In Organic Farming: An International History, ed. W Lockeretz, 9–29.

Wallingford, U.K., CABI Lori, M., Symnaczik, S., Mader, P., de Deyn, G., Gattinger, A., 2017. Organic farming enhances soil microbial abundance and activity a meta-analysis and meta-regression. PLOS ONE 12:e0180442

Wallingford, U.K., CABI, W.B.A. (Wiss. BeiratAgrarpolitik). 2016. Klimaschutz in dery Land- und Fors twirts chaftsowie den nachgelagerten Bereichen Ern ahrung und Holzverwendung. Gutacht. WBA/WBW, Nov. 2016, Bundesminist. Ernahr. Land wirtsch, Berlin Weber JG. 2011. How much more do growers receive for Fair Trade-organic coffee? Food Policy 36:678–85

White, R.R., Hall, M.B., 2017. Nutritional and greenhouse gas impacts of removing animals from US agriculture. PNAS 114:E10301–8

Willer, H., Lernoud, J., eds. 2017. The world of organic agriculture. Statistics and emerging trends 2017. Rep., FIBL/IFOAM, Frick, Switz.

Wollni, M., Andersson, C., 2014. Spatial patterns of organic agriculture adoption: evidence from Honduras. Ecol. Econ. 97, 120–28

WebPages

https://shop.fibl.org/CHen/mwdownloads/download/link/id/ 785/?ref=1
http://www.agbioworld.org/newsletter_wm/index.php?
http://www.green peace org
http://www.ifoam.bio/en.
https://www.researchgate.net/publication/300881600
https:// www.inea.it
https:// www.inea.it