A Seminar Paper
on

Impacts of Organic Agriculture on the Environment and Food Quality

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Impacts of Organic Agriculture on the Environment and Food Quality[1]

By

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ABSTRACT

Negative environmental impacts and food quality degradation associated with intensive chemical fertilization in conventional agriculture have motivated growers to pursue organic agriculture. Organic agriculture aims for human welfare without harming the environment and keeping the produce quality intact. Various parameters of environment and food quality were discussed in this review paper and superiority of organic agriculture was found. Soil organic carbon content in organic agriculture was 1.7 times of conventional agriculture; the content of alkali nitrogen, available phosphorus and available potassium were also significantly higher in organic system. The mean % soil organic matter was 7.37 for conventional and 8.33 for organic samples. Humic substances and humification potential were also higher in organic system. Organic farming decreased mean sediment delivery by 30% compared to conventional farming. Soil structure, aggregate stability, carbon and nitrogen mineralization were greater under organic farming. Organic agriculture showed clear benefits for biodiversity by hosting 30% more species and 50% more individuals. Application of compost, green manure and forage legumes improved water quality and reduced nitrate leaching. Subsurface drainage water nitrate loss from the conventional system (79.2 kg ha^{-1}) was twice than organic (39.9 kg ha^{-1}). Greenhouse gas emissions were also lower in organic system. Organic crops contained less pesticide residues including nitrates and nitrites; more dry matter, essential amino acids and total sugars. 27% more vitamin C and 119% more phenolic compounds were seen in organic fruits and vegetables. Organic crops also contained statistically more mineral compounds and usually have better sensory and long-term storage qualities. Non-renewable energy use, global warming, acidification and eutrophication potential were 50% less in organic soybean crop.

Keywords: Soil organic matter, nitrate contamination, greenhouse gas, antioxidants, minerals

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CHAPTER I

INTRODUCTION

Green revolution was introduced to compete with the increasing food demand for the increasing world population. It has been successfully feeding the growing world population, but large-scale land conversion and excessive application of synthetic fertilizers and pesticides have led to considerable adverse impacts on environment and human health, such as soil quality degradation, water eutrophication, groundwater pollution, accumulation of heavy metal, greenhouse gas emissions and biodiversity losses (Smith *et al.,* 2013) (Wang *et al.,* 2021). Conventionally grown crops contain four times more pesticide residue and significantly higher levels of the toxic heavy metal cadmium which is a concerning matter of present time (Bickel & Rossier, 2015). Sustainability in agriculture is one of the major concerns of humanity today. To preserve the environment and to maintain quality of the produce, alternative production technique like organic agriculture are being popular.

Based on the principles of health, ecology, fairness and care; organic agriculture (OA) ensures a sound and healthy environment (IFOAM, 2005). Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity (Moeskops, 2019). It improves soil fertility through practicing scientific crop rotation, planting legumes and the application of organic fertilizers; and at the same time prohibiting the use of any synthetic fertilizers and pesticides to maintain a sustainable agricultural system (Aulakh *et al.,* 2022). Organic system is healthier for soil health and a critical tool for sequestering carbon in the soil, thus mitigating climate change through long-term greenhouse gas reduction (Ghabbour *et al*., 2018). It increases soil organic carbon (SOC), available nitrogen (N), phosphorus (P) and potassium (K) (Tong *et al*., 2022). Organic farming significantly increases soil microbial diversity through applying organic fertilizers free of harmful chemicals, which protects the soil from pathogen infection and helps in degrading external pollutants (Gömöryová *et al.,* 2011). Soil degradation through soil erosion is also reduced in OA as soil structure, stability, water infiltration and water retention capacity is improved (Seitz *et al*., 2019).

Organic food contains fewer pesticide residues including nitrates and nitrites and more vitamin C, essential amino acids and total sugars (Rembiałkowska, 2007). They are characterized by a significantly higher content of dry matter and higher antioxidant activity including total polyphenols and phenolic acids (Ponder & Hallmann, 2019). Organically grown crops reduces storage loss as they are rich in dry matter content and thus increase economic value or profit (Rembiałkowska, 2007).

Besides the enormous positive environmental impacts, OA is not that much exercised throughout the world. The reason maybe decreased yield. Organic yields were found 19.2% lower than conventional yield, but it could be substantially increased by multi-cropping and crop rotations (Ponisio *et al*., 2015). The diversification of cropping systems can make more efficient use of available nutrients, with improved yield and economic performance, which is crucial in times of limited nutrients and financial constraints (Zhang & Li, 2003). But the cost analysis and yield factors are not discussed here. This review paper is strictly confined within the impacts of OA on the environment and food quality.

Considering the facts, present study was undertaken with the following objectives:

1. To compare different environmental and food quality parameters between organic and conventional agriculture.
2. To assess superiority or inferiority of organic agriculture based on those comparison.

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CHAPTER II

MATERIALS AND METHODS

The purpose of this seminar paper is to provide a review, and all information presented here was obtained from secondary sources. The sources used included books, journal articles, reports, internet searches, conference proceedings. I was fortunate to receive sufficient guidance from my major professor and course instructors, which proved helpful in completing my seminar paper. The collected information was then compiled and arranged chronologically to create this seminar paper.

CHAPTER III

REVIEW OF FINDINGS

3.1 Organic agriculture

International Federation of Organic Agriculture Movements (IFOAM, 2005) defines organic agriculture as a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved.

Organic farming is based on four core principles (IFOAM, 2005) and they are:

1. Health: Organic agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
2. Ecology: Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
3. Fairness: Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
4. Care: Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

Organic agriculture follows various environment friendly techniques that sustain soil fertility for a long time. Vermicompost, kitchen waste and sludge, green leaf manures, crop rotation, biological management, bio-fertilizers, bio-pesticides and manures are few of the important elements (Table 1)

Table 1. Elements of organic agriculture and their roles and impacts

Elements	Roles and Impacts
Vermicomposting, Kitchen waste and Sludge	• Improve biological and physiochemical properties of soil and soil aeration. • Enrich soil with nutrients and restore friendly microbial species.

Table 1. Elements of organic agriculture and their roles and impacts (Continued)

Elements	Roles and Impacts
Green leaf manures	• Help in mineralization of insoluble plant minerals. • Act as a carbon source for soil microorganisms. • Enhance water holding capacity and regulate soil temperature.
Crop Rotation	• Control pest, weeds and diseases. • Maintain soil fertility and improve soil stability. • Ensure higher yields. • Conserve water while reducing soil and water contamination. • Create a healthy environment for biotic and abiotic interactions.
Nitrogen Fixing Microorganisms	• Free-living (*Cyanobacteria, Nostoc, Anabena, Clostridium, Azotobacter*) and symbiotic bacteria (*Rhizobium, Frankia, Azospirillum*) initiate root nodule formation. • Ensure nitrogen availability in soil.
Bio-fertilizers	• Enhance uptake of nutrients in the rhizosphere of plants. • Regulate the nutrient balance of soil. • Convert insoluble phosphate in soluble forms.
Bio-pesticides	• Protect plants from a variety of diseases and control soil born fungal pathogens. • Less toxic with high specificity.
Manures	• Enhance crop growth and soil productivity. • Increase uptake of humic substances or its decomposition products and affect favorably towards the growth and yield of plants. • It increases beneficial soil microorganisms and their activities and thus increases the availability of major and minor plant nutrients.

(Source: Kumawat *et al*., 2022)

Organic farming is low input farming and uses natural sources of nutrients which include compost, manure, crop residues and natural methods of crop and weed control, instead of using synthetic or inorganic agrochemicals (Gao *et al*., 2017).

3.2 Impact on soil

Soil is one of the most valuable resources that plays a fundamental role in agriculture. Healthy soil is essential for growth and evolution of healthy plants. Organic agriculture increases soil organic matter (SOM), soil biological activity (by 30-100%), edaphon biomass (by 50-80 %), improves physical and chemical soil properties and reduces erosion (Moudry & Moudry, 2014). Organic agriculture had 32% to 84% greater microbial biomass carbon, nitrogen and total phospholipid fatty-acids than conventional systems (Lori *et al*., 2017).

3.2.1 Impact on soil organic matter storage

Soil organic matter is a key attribute of soil quality which makes up just about 2–10% of most soil's mass but has an important role in nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, and carbon sequestration (Edwards, 2022). Soil organic carbon (SOC) is a quantitative component of SOM. It is a function of the net effect of two processes; carbon deposition from crop residues and organic amendments versus carbon losses from soil respiration and SOC decay (Janzen, 2006).

Tong *et al*., (2022) compared the SOC content of three cultivation technique (organic, conventional and low-input). After 15 years, SOC content in the organic cultivation was 1.7 times of that in conventional cultivation and 1.2 times of low-input cultivation (Figure 1). Soil organic matter are managed through organic fertilizers (manure, compost), crop residues (mulches) and crop rotations (including legumes with nitrogen fixation) under OA replacing the application of chemical fertilizers in intensive, nonorganic agriculture (Birkhofer *et al*., 2016). Organic fertilizers are more easily converted into SOM and available nutrients. Soil organic carbon content increased with increasing input of organic fertilizers (Gattinger *et al*., 2012). Increased SOC content improved soil structure, promoted mineralization and increased soil fertility (Tong *et al*., 2022).

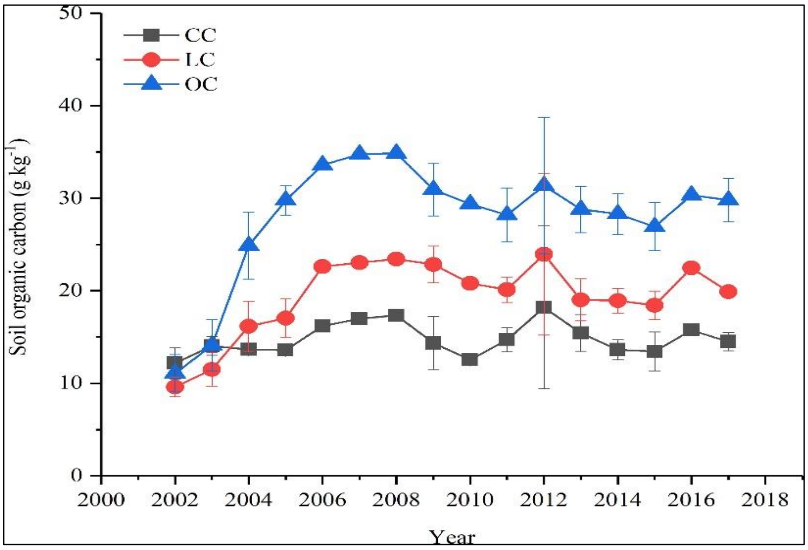


Figure 1. Soil organic carbon content of three cultivation methods from 2002 to 2017

(Source: Tong *et al*., 2022)

Pulleman *et al*., (2003) found 1.6 times more SOM in OA (24 g kg^{-1}) compared to conventional one (15 g kg^{-1}) and concluded that the long-term application of animal manure resulted in increased SOM content that also improved soil structure. The median SOM content was 7% higher in organic farms (Tuomisto *et al*., 2012).

The humic substances level is related with long-term soil health, water retention, nutrient storage and improved texture and permeability (Ghabbour *et al*., 2018). Humic acids and fulvic acids are main components of humic substances. Conventional agricultural practices reduce humic substances and depress soil's productivity. Soil organic matter, humic substances including humic acid and fulvic acid were significantly higher in OA (Figure 2). Organic agriculture leads to more SOM sequestration, it is healthier for soil and a critical tool for sequestering carbon in the soil, thus mitigating climate change through long-term greenhouse gas reduction (Ghabbour *et al*., 2018).

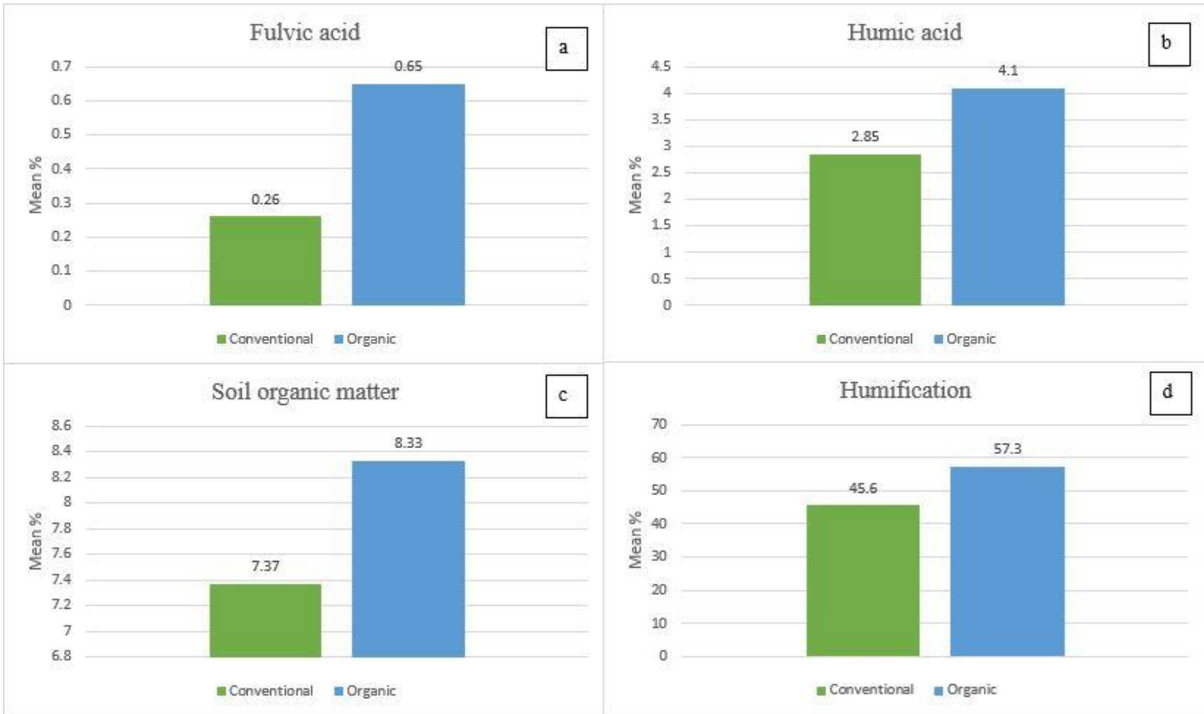


Figure 2. Mean levels of fulvic acid (a), humic acid (b), soil organic matter (c) and humification (d) in organic and conventional agriculture

(Source: Ghabbour *et al*., 2018)

The explanation for higher organic matter contents in OA might be the increased decomposition of organic residues by microorganisms (Birkhofer *et al*., 2008), less intensive tillage and inclusion of leys in the rotation (Canali *et al*., 2009).

3.2.2 Impact on soil available nutrients content

The content of alkali hydrolyzed nitrogen (N), available phosphorus (P) and available potassium (K) in organic cultivation were significantly higher than conventional and low-input cultivation technique (Figure 3). Compared with conventional agriculture, available N increased by 26.88%-135.08%, available P increased by 22.25% -210.12%, available K increased by 4.37% -110.87% in OA.

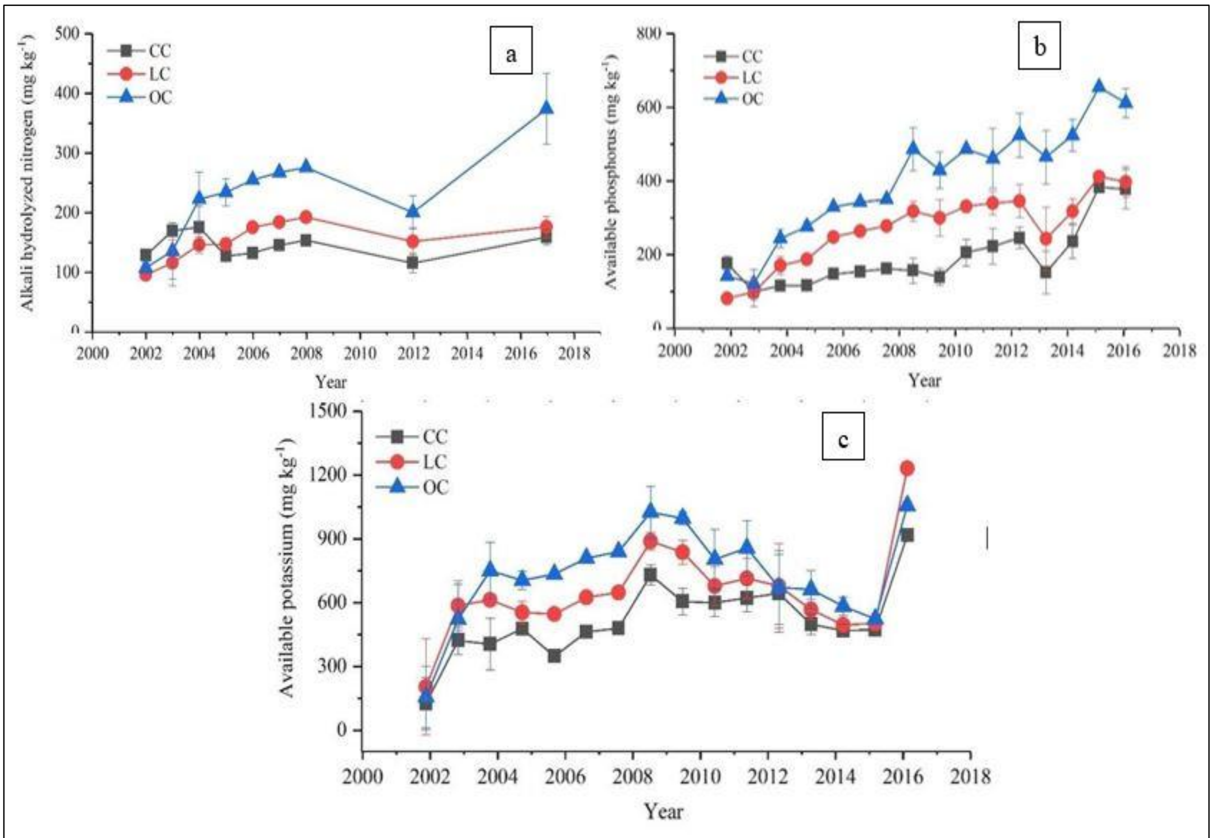


Figure 3. Soil available alkali hydrolyzed nitrogen (a), phosphorus (b) and potassium (c) content of different cultivation methods from 2002 to 2017

(Source: Tong *et al*., 2022)

Both carbon (C) and N mineralization were 1.7 times greater in OA than in conventional agriculture (Table 2). Higher nutrient uptake under OA might be due to better soil health and less nutrient fixation leading to higher biomass production and nutrient removal by plants (Das *et al*., 2017). The total removal or uptake of N, P and K under OA was significantly ($p = 0.05$) higher than inorganic farming practices (Figure 4). The increased N uptake was due to mineralization of N from continuous application of organic amendments and mineralization effect upon native N (Das *et al*., 2017)

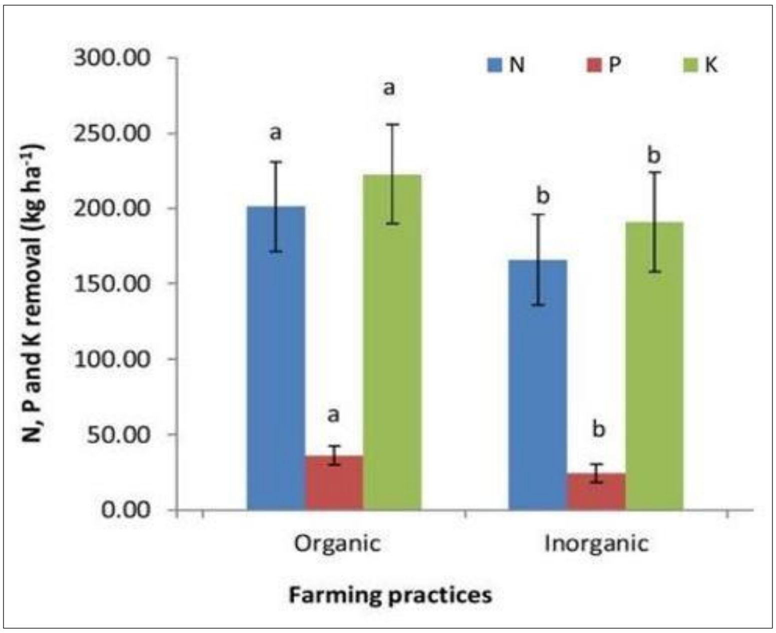


Figure 4. Total removal of NPK as influenced by farming practices (means with the same letter are not significantly different at $p = 0.05$)

(Source: Das *et al*., 2017)

The decomposition of organic manure results in the formation of CO_2, which helps in the solubilization of the native P and forms complexes that can be easily assimilated by the plants; and protective cover of sesquioxide particles reduces the P fixing capacity of the soil making P readily available to plants for uptake (Das *et al*., 2004).

3.2.3 Impact on soil erosion and soil stability

Soil physical properties like aggregate stability, water holding capacity and bulk density contribute to the resistance of soils against structural degradation and reduces nutrient leaching. Soil physical quality is often higher under organic agriculture (due to higher earthworm activity), which contributes to the lower soil erosion (Birkhofer *et al*., 2016).

Organic agriculture decreased mean sediment delivery by 30% (0.54 t ha^{-1} h^{-1}) compared to conventional treatments. This finding was confirmed separately in 2014 (54%, 0.17 t ha^{-1} h^{-1}) and 2017 (27%, 0.92 t ha^{-1} h^{-1}) (Figure 5). Increased SOM and living plant cover in OA appeared to protect soil surfaces better than conventional plots and soil erosion rates were significantly lower when soil surface cover was above 30% (Seitz *et al*., 2019).

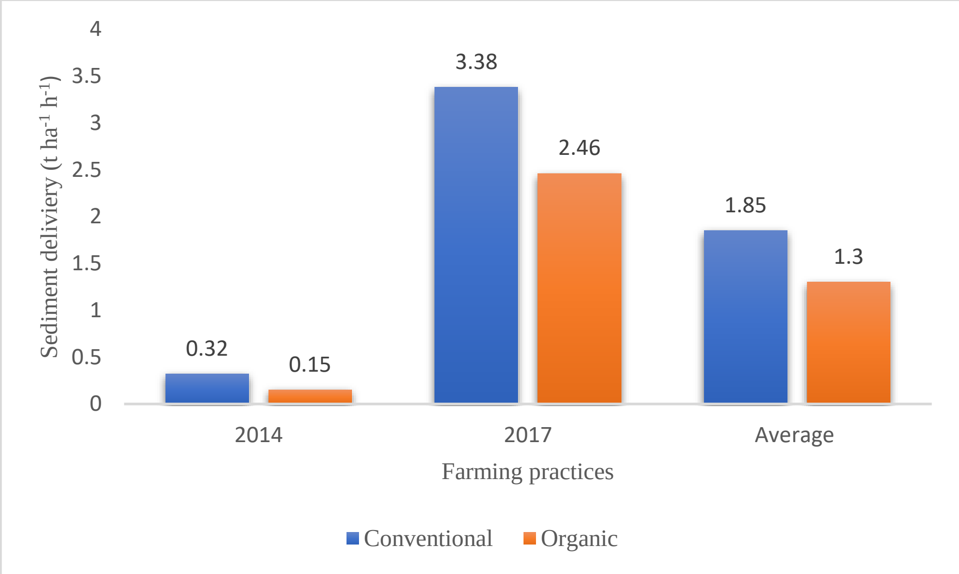


Figure 5. Sediment delivery (t ha^{-1} h^{-1}) in organic and conventional treatments

(Source: Seitz *et al*., 2019)

The mean weight diameter (MWD) of dry sieved aggregates was significantly greater in OA (17 mm) compared with conventional system (13 mm) (Pulleman *et al*., 2003).

Table 2. Carbon and Nitrogen mineralization, % reduction of mean weight diameter and water-stable macro aggregation of conventional and organic agriculture

Depth (cm)	Field	Carbon mineralization (mg C kg^{-1})	Nitrogen mineralization (mg C kg^{-1})	Reduction of mean weight diameter (%)	% water stable macro aggregation
0-10	Organic	490 (1.9) ^{B}	32.8 (1.5) ^{A}	67.6 (6.8) ^{C}	75.0 (1.8) ^{B}
	Conventional	282 (2.3) ^{A}	22.8 (1.0) ^{A}	95.6 (0.6) ^{B}	43.7 (4.2) ^{A}
10-20	Organic	437 (0.9) ^{B}	47.2 (2.3) ^{B}	78.0 % (2.5) ^{A}	70.3 (1.8) ^{B}
	Conventional	245 (1.4) ^{A}	23.4 (0.6) ^{A}	96.3 % (0.3) ^{C}	41.2 (3.3) ^{A}
Average	Organic	464	40	72	73
	Conventional	264	23	96	43

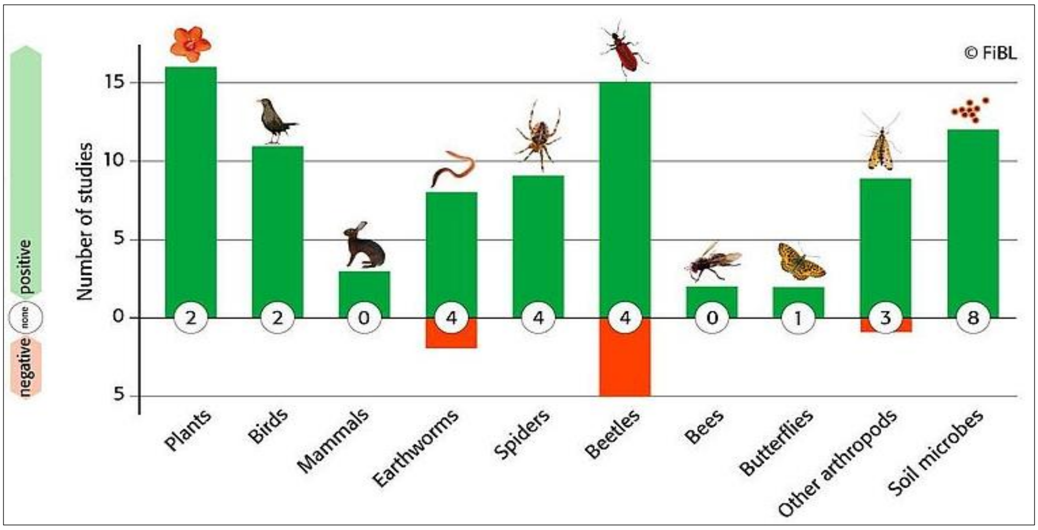
Values in parentheses are standard errors (n=4). Values followed by different superscript capital letters are significantly different between the fields.

(Source: modified from Pulleman *et al*., 2003)

Total water-stable macro aggregation after wet sieving amounted to 75% in OA compared with 43% in conventional system (Table 2). These results can be explained by an increase in total SOM content and greater earthworm activity (Pulleman *et al*., 2003).

3.3 Impact on biodiversity

Birds, predatory insects, spiders, soil dwelling organisms and field flora benefited most from OA (Figure 6). Organic farming increased species richness by about 30% (Tuck *et al*., 2014). Also, organically managed fields had on average 30% more species and 50% more individual than conventionally managed fields (Bengtsson *et al*., 2005). More diversified crop rotation, no chemically synthesized pesticides, conservation tillage and preservation of SOM and fertility in OA are the main reasons behind increased biodiversity (FiBL, 2011).



*Green bar indicates positive effect; red bar indicates negative effect; number in white circle indicates no effect.

Figure 6. Number of studies that shows positive, negative or no effect of organic agriculture on biodiversity

(Source: FiBL, 2011)

A higher supply of organic matter through crop residues and organic fertilizers creates favorable living conditions for soil fauna. The fertile soil provides a habitat for a large number of various organisms. Those organisms play an important role in SOM decomposition and inorganic substances transformation where plants can easily uptake nutrients and they also enrich humus reserves in the soil (Moudry & Moudry, 2014)

3.4 Impact on greenhouse gas emissions and climate change mitigation

Agriculture is responsible for 18.4% of global greenhouse gas (GHG) emissions (Figure 7). If deforestation due to land conversion to agriculture were taken into account, it could bring the total share of agricultural emissions to approximately one-third of global anthropogenic GHG emissions (Scialabba & Mller-Lindenlauf, 2010). This makes agriculture a major sector that must be considered in attempts to mitigate global climate change.

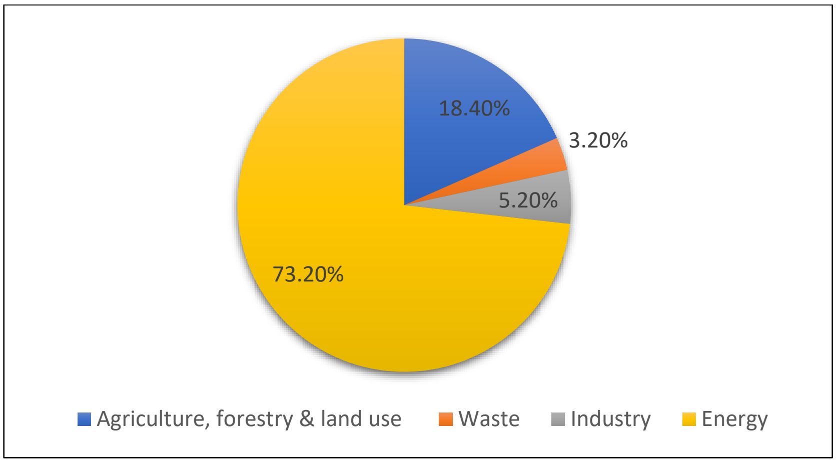


Figure 7. Greenhouse gas emission by sector

(Source: Ritchie *et al*., 2020)

The fundamental difference between the conventional and organic farming system in terms of GHG emissions is obvious within fertilization as the use of synthetic fertilizers within the conventional system increase emissions. During fertilization of organically grown wheat, only 31.2% of CO_2 produced within fertilization of conventional wheat is released. With rye, it is only 16.6% of conventional farming. For carrot, cabbage, tomato, potato and onion it was 17.9%, 19.4%, 30.3%, 37.8% and 53.3% of conventional agriculture emission respectively (Figure 8).

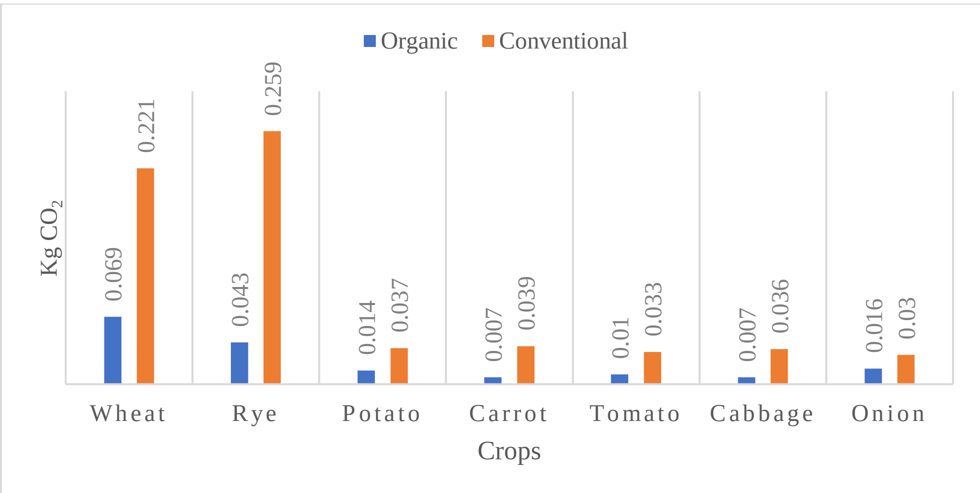


Figure 8. Greenhouse gas emissions (Kg CO_2 kg^{-1}) within fertilization of selected crops in conventional and organic agriculture system

(Source: Moudrý *et al*., 2013)

The emission reduction potential of organic agriculture by not using chemical fertilizers is calculated to be about 20% and the compensation potential by carbon sequestration to be about 40–72% of the world's current annual GHG emissions (Scialabba & Mller-Lindenlauf, 2010). Under extreme drought conditions there was 15-20% greater movement of water through soils in OA; water capture and retention capacity was also up to 100% higher (Müller *et al*., 2016) (FiBL, 2016). Environmental impacts of organic soybeans with regard to non-renewable energy use, global warming, acidification and eutrophication potential per ton produced were approximately 50% less than the impacts for the conventional soybeans though land use requirements were 12% higher (Figure 9).

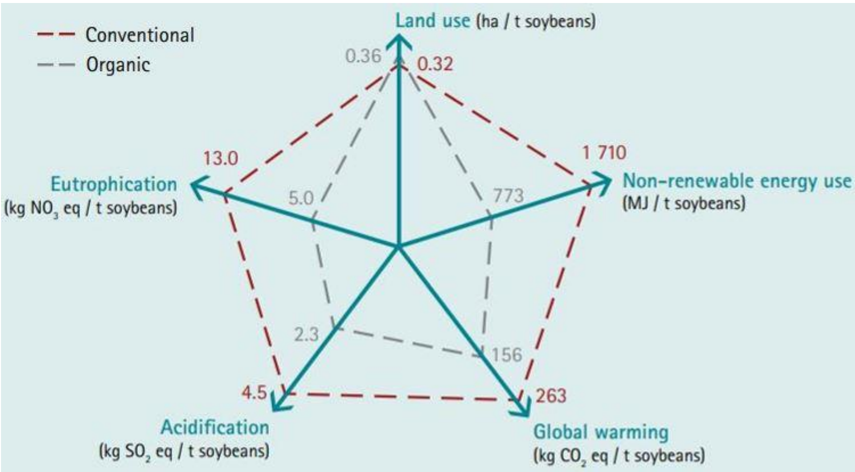


Figure 9. Environmental impacts from organic and conventional soybean

(Source: FAO, 2011)

Subsurface drainage water nitrate loss for the entire 3-year period from the conventional system was nearly twice as much as the nitrate loss from the organic system (Table 3).

Table 3. Annual subsurface drainage water nitrate concentration (mg L^{-1}) and nitrate loss (kg ha^{-1})

Year	Cropping system	Nitrate Concentration (mg L^{-1})	Nitrate loss (kg ha^{-1})
2012	Organic	8.8	7.7
	Conventional	10.9	10.1
2013	Organic	8.8	17.7
	Conventional	19.4	34.7
2014	Organic	7.2	14.5
	Conventional	18.1	34.4
Total	Organic	24.8	39.9
	Conventional	48.4	79.2

(Source: Cambardella *et al*., 2015)

The 3-year nitrate losses represented 5.8% of applied N in the organic cultivation and 15.4% of applied N in the conventional cultivation. The conventional system lost 100% and 132% more nitrate in subsurface drainage water than the organic system in 2013 and 2014, respectively (Cambardella *et al*., 2015). Nitrogen leaching per unit area was 31% lower in organic farming compared to conventional farming (Tuomisto *et al*., 2012). The main explanation for lower N leaching levels from OA is the lower levels of N inputs applied and higher N leaching levels in conventional farming is due to poor synchrony between the nutrient availability and crop's nutrient intake (Korsaeth, 2008).

3.5 Impact on food quality

Organic crops in comparison to the conventional ones are richer in antioxidants while containing less undesirable pesticide residues and nitrates (Kazimierczak *et al*., 2019). Compared with conventional raspberry leaves, organic raspberry leaves were characterized by a significantly higher content of dry matter and higher antioxidant activity including total polyphenols and phenolic acids (Ponder & Hallmann, 2019). Enhancement in phenol, chlorophyll, ascorbic acid, oxalic acid, acidity, lycopene and carotenoid contents due to application of organic manure had been reported; along with the significant effect of organic manures and crop rotation on yields and crop quality (Ramesh *et al*., 2008). Organic food usually have better taste and sensory quality (Rembiałkowska, 2007).

3.5.1 Impact on pesticide residues

Organic food contained significantly lower amounts of pesticide residues than conventional food (Figure 10).

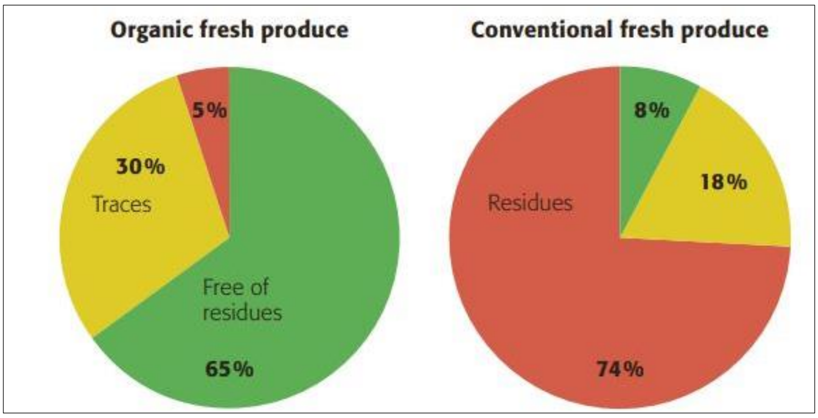


Figure 10. Pesticide residues on organic and conventional fruits and vegetables
(Source: Bickel & Rossier, 2015)

Exposure to nitrite is considered a risk factor for gastric cancer and methemoglobinemia of newborn babies, children and the elderly (Matt *et al*., 2011). Organic crops contained fewer nitrates (Table 6) due to not using any synthetic fertilizers (Kazimierczak *et al*., 2019).

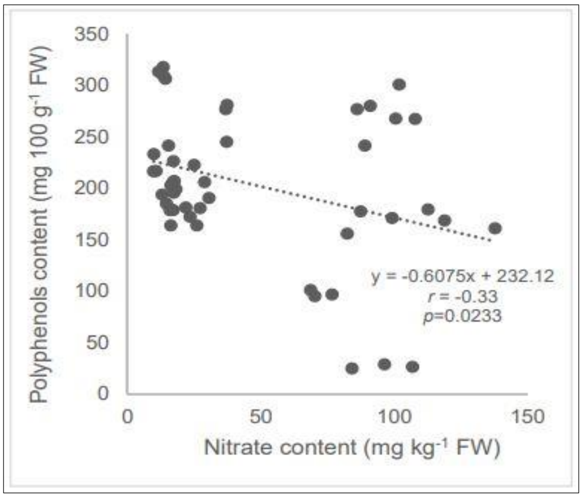


Figure 11. Correlation between the nitrates and polyphenols content

(Source: Kazimierczak *et al*., 2019).

An inverse relationship between the content of nitrates and polyphenols in potato tubers was identified (Figure 11) (Table 6). At the same time, potatoes from organic production were, on average, richer in polyphenolic compounds (phenolic acids and flavonoids).

3.5.2 Impact on vitamins and minerals content

58% of research on the impact of agricultural production methods on the content of vitamin C in vegetables and fruits indicates its higher content in plant materials from organic versus conventional farming (Herencia *et al*., 2011). It was also confirmed by Barański *et al*., (2014).

Table 4. Mean percent difference in nutrient content of organic versus conventional crops

Nutrient	Mean % difference
Vitamin C	+27.0%
Iron	+21.1%
Magnesium	+29.3%
Phosphorus	+13.6%
Nitrates	-15.1%

*Plus, and minus signs refer to conventional crops as the baseline for comparison. For example, vitamin C is 27.0% more abundant in the organic crop (conventional 100%, organic 127%).

(Source: Worthington, 2001)

Organic crops contained significantly more vitamin C, iron, magnesium, and phosphorus and less nitrates (Table 4). For example, the vitamin C content of an organic fruit or vegetable is 27% more than conventionally grown fruit or vegetable (if an average conventional fruit or vegetable contained 100 mg of vitamin C, then an organic one would contain 127 mg).

Table 5. Mean percent difference in nutrient content of five most studied vegetables between organic and conventional vegetables

Vegetable	Vitamin C	Iron	Magnesium	Phosphorus
Lettuce	+17	+17	+29	+14
Spinach	+52	+25	-13	+14
Carrot	-6	+12	+69	+13
Potato	+22	+21	+5	0
Cabbage	+43	+41	+40	+22

*Plus, and minus signs refer to conventional crops as the baseline for comparison. For example, vitamin C is 17.0% more abundant in organic lettuce (conventional 100%, organic 117%)

(Source: Worthington, 2001)

The organic crop had a higher mean mineral content for all 21 minerals considered in the analysis of Worthington (2001) . In addition, there might be less of the toxic heavy metals in organic crops than in conventional crops.

Worthington (2001) explained the reasons behind more vitamins and minerals content of organic foods. The abundant microorganisms present in OA produced compounds (citrate and lactate) that combined with soil minerals and made them available to plant roots. The presence of these microorganisms partially explains the higher mineral content of organic food crops. Nitrogen from any kind of fertilizer affects the amounts of vitamin C and nitrates. When a plant is presented with a lot of nitrogen, it reduces carbohydrate production. As vitamin C is made from carbohydrates, the synthesis of vitamin C is reduced also. Excess nitrogen is accumulated as nitrates. As organically managed soils generally present plants with lower amounts of nitrogen than chemically fertilized soils, organic crops had more vitamin C and less nitrates. Potassium fertilizer can reduce the magnesium and phosphorus content of plants. Given the plant responses just described, it would be expected that the organic crops would contain larger amounts of magnesium and phosphorus than comparable conventional crops.

3.5.3 Impact on antioxidants

Polyphenols are important pro-healthy compounds. Potato tubers from organic production were significantly richer in polyphenols including phenolic acids and flavonoids in comparison to the conventional ones (Table 6). Mineral nitrogen fertilizers, especially their high doses, reduce the content of phenolic compounds in vegetables and fruits in conventional farming (Bloksma *et al*., 2007). In plants from OA grown on natural fertilizers, a higher synthesis of polyphenolic compounds is usually observed. The non-use of synthetic pesticides in OA increases the exposure of plants to stress factors, which may lead to the intensive production of secondary metabolites as a defense mechanism (Wegener *et al*., 2014)

Table 6. The content of dry matter (%), nitrate (mg kg^{-1}), polyphenols (mg kg^{-1}), phenolic acids (mg kg^{-1}) and flavonoids (mg kg^{-1}) of tubers in organic and conventional system

	Dry matter (%)	Nitrate (Mg kg^{-1})	Polyphenols (Mg kg^{-1})	Phenolic Acids (Mg kg^{-1})	Flavonoids (Mg kg^{-1})
Conventional	21.47 ± 1.51^{A}	236.27 ± 46.41^{B}	190.0 ± 83.9^{A}	143.5 ± 84.5^{A}	46.5 ± 17.1^{A}
Organic	22.49 ± 1.69^{B}	169.76 ± 77.33^{A}	768.2 ± 354.4^{B}	704.5 ± 349.9^{B}	63.7 ± 11.5^{B}

Data are presented as mean ± SD with ANOVA p-value. Means in the same column followed by the same letter are not significantly different ($p < 0.05$) by Tukey's test.

(Source: Kazimierczak *et al*., 2019)

Rembiałkowska (2007) found 119.3% more phenolic compounds in organic food compared to conventional one. Plant-based phenolic metabolites are particularly interesting because of their potential antioxidant activity and medical properties, including anticarcinogenic activity (Brandt & Mølgaard, 2001). Organic farming has elevated antioxidant levels in about 85% of the cases studied and, on average, levels are about 30% higher compared with foods grown conventionally (Benbrook, 2005).

3.5.4 Impact on dry matter content

In general, a significant relation was found between farming system and dry matter content in tubers. On average, organic potatoes contained significantly more dry matter (Table 6). Higher content of dry matter in plants from organic farming is usually observed, especially in root and leafy vegetables (Lairon, 2010). This is most probably related to the type and doses of fertilizers used in cultivation. High dose mineral fertilization often used in conventional agriculture is responsible for excessive vegetative growth and reduction of dry matter content in agricultural crops (Stefanelli *et al.*, 2010)

3.5.5 Impact on storage

Transpiration losses and decay processes, as well as changes in nutritive value, normally take place during the storage period of fruits and vegetables. The decay process is slower in organic crops, which therefore show better storage quality after the winter period.

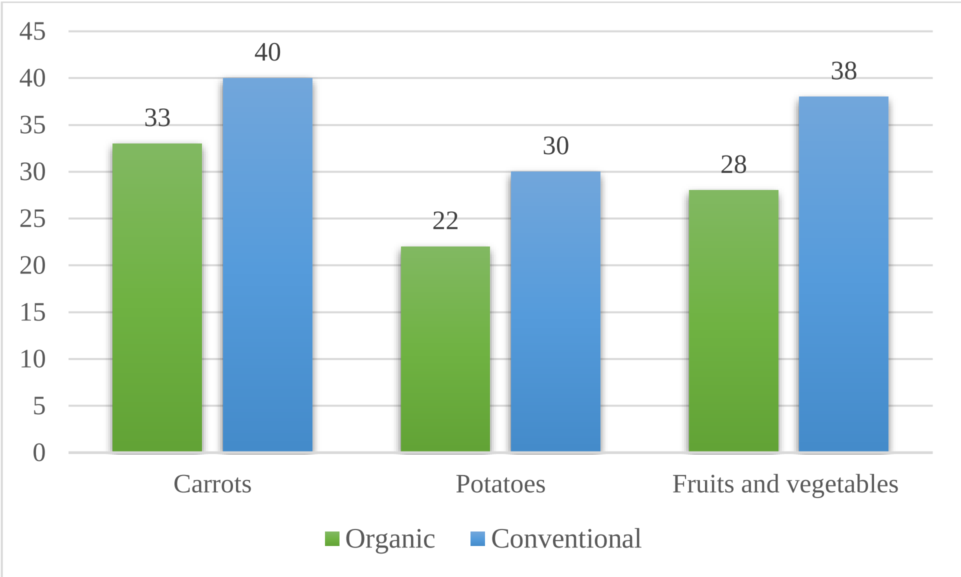


Figure 12. Storage loss (% of initial mass) of carrots, potatoes and various fruits and vegetables from organic and conventional farms

(Source: Rembiałkowska, 2007)

The storage quality of vegetables and fruits was better in the case of plants grown on organic farms (Figure 15).The reason behind better storage quality of organic crops might be associated with higher content of dry matter in their flesh, causing less extensive decay and decomposition (Rembiałkowska, 2007). Less storage losses in OA have not only nutritive but also economic benefits. In conventional systems, thought high yields are achieved, significant losses during storage reduce the economic benefits.

CHAPTER IV

CONCLUSION

This review paper compared organic agriculture with conventional agriculture on different parameters of environment and food quality. In case of environment, the parameters chosen were soil organic matter, soil available N, P, K, soil erosion and stability, biodiversity and greenhouse gas emission. For food quality, the parameters were pesticide residues, nitrate content, dry matter content, vitamins and minerals content, antioxidants content and storage loss.

In all the studied parameters, organic agriculture showed superiority over conventional practices. The average %SOM was 7.37 for conventional and 8.33 for organic samples. Fulvic acid % mean values were 0.26 and 0.65. The humic acid % mean values for conventional and organic farm soils were 2.85 and 4.1, respectively. The mean % humification was 45.6 for conventional soils and 57.3 for organic. Compared with conventional agriculture, available N increased by 26.88%-135.08%, available P increased by 22.25% -210.12%, available K increased by 4.37% -110.87% in OA. Uptake or removal of N, P and K under OA was significantly higher than inorganic farming practices. Carbon and N mineralization were 1.7 times greater in OA than in conventional system. Organically farmed areas had 30% more species and 50% more individual than non-organic areas. Organic agriculture decreased mean sediment delivery by 30%. Nitrate loss through water for conventional system (79.2 kg ha^{-1}) was approximately 2 times compared with OA (39.9 kg ha^{-1}). During fertilization, GHG emission from organically grown wheat, rye, carrot, cabbage, tomato, potato and onion was reduced by 31.2%, 16.6%, 17.9%, 19.4%, 30.3%, 37.8% and 53.3% respectively compared with conventionally grow crops. Environmental impacts of organic soybeans with regard to non-renewable energy use, global warming, acidification and eutrophication potential per ton produced were approximately 50% less than conventional soybeans. Organic foods were 65% free of pesticide residues whereas there were 74% residues on conventional produce. Organic fruits and vegetables contained 27% more vitamin C, 21.1% more iron, 29.3% more magnesium, 13.6% more phosphorus and 15.1% less nitrates. Organic foods were characterized by more dry matter and antioxidants including different polyphenols, phenolic acids and flavonoids. Organic food also showed better storage quality. It can be concluded that organic agriculture had a positive impact on environment and food quality.

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