



Toward Conventional or Organic Agriculture? A Sustainability Check from Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RAB, TEL and NKC designed the study and wrote the protocol. Author ONMF collected the field data under the supervision of authors RAB, NKC and ONMF. Author RAB managed the analyses of the study. Authors RAB and TEL wrote the first draft of the manuscript and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The environmental advantages of organic over conventional agriculture have gained increasing importance in the last decades. The organic agriculture discourse has been mainly propelled by food-sufficient countries in the West and the emerging economies in Asia. Strangely, it has not attracted similar attention in Sub-Saharan Africa where agriculture plays a significant role in the economy, is a key livelihood activity for most inhabitants and food insufficiency is rampant. The objective of this paper is to comparatively analyze sustainability aspects of conventional and organic agriculture, using the common cabbage, *Brassica oleracea L. var. capitata*.

Study Design: We apply the randomized complete block design.

Place and Duration of Study: Centre de Formation du Noun (CEFAN), in Noun division, in the western region of Cameroon, between August and October 2016.

Methodology: 1250 cabbage plants were planted on 10 equal and randomly selected plots. 5 replications were each subjected to conventional and organic practices. Plant parameters such as

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leaf area, plant height, survival rates, plant yields and soil pH were recorded from randomly selected plants from all plots, and used to estimate economic and ecological sustainability dimensions.

Results: Data analysis revealed that all captured parameters with the exception of soil pH were higher on average in the conventional agriculture plots. Survival rates and subsequent gross margin were significantly higher for conventionally cultivated cabbages ($X^2=.05$, $P=.04$ respectively).

Conclusion: We therefore conclude that in agriculture-dependent economies at lower levels of development where market differentiation is highly deficient, conventional agriculture should be the preferred practice.

Keywords: Sustainability; conventional agriculture; organic agriculture; Cameroon.

ACRONYMS AND ABBREVIATIONS

CEFAN : Centre De Formation De Noun

FCFA : Franc de la Communauté Française de l'Afrique

FYM : Farm Yard Manure

GDP : Gross Domestic Product

GM : Genetically Modified

MASL : Meters above sea level

NPK : Nitrogen Phosphorus and Potassium

pH : Potential of Hydrogen

USD : United States Dollar

1. INTRODUCTION

Concerns on the environment, its impacts on agricultural production, and the contribution of agriculture to global warming have raised questions about the sustainability of some agricultural practices and methods [1]. Proponents of environmentally friendly agriculture (also known as organic farming) seem to believe that it has enormous potentials to produce sufficient food for the world's population, while inflicting only little or no harm at all to existing ecosystems. Organic farming has the potential to conserve water, soil, air and associated biological resources, reduce food miles and the consumption of fossil fuels, thereby contributing to gains in the climate change reduction front [2,3]. In fact, the relevance of organic agriculture and its linkage to global climate change is currently common knowledge. This has led to policy prescriptions that promote organic farming in many individual countries [4]. The romantic image of organic agriculture has been further promoted by the strong emphasis on combating climate change, as indicated in the global Sustainable Development Goals – the SDGs [5].

The global concern for the environment is causing organic agriculture to drift away from a rather rhetoric position, towards an obligatory reality in some parts of the world. This explains

why [6] for instance contends that the area under organic agriculture has increased many folds in recent years in many parts of India. Though organic agriculture was more profitable than the inorganic one, the authors [6] argue that lower productivity levels that characterize organic farming are likely to be accompanied by food security challenges. In a similar study to understand the future of organic farming in Thailand, [4] reported an adoption rate of around 50% amongst the pilot farmers. Significant determinants for adoption were related to loyalty to GOs and NGOs, availability of organic manure and the perceptions of the effects of pesticides on the environment. In a much more systematic study for over 40 years, [2] found out that the major gains of organic over inorganic agriculture were registered in reduced soil erosion and increased soil productivity.

A critique frequently labelled on organic farming has been its lower yields compared to conventional agriculture [3,6]. But this critique has not been accepted without resistance. Using linear programming approach, [3] for instance argue that organic farming can feed the entire population of Turkey, as long as existing constraints can be minimized and potentials optimized.

The cultivation of the common cabbage (*Brassica oleracea L. var. capitata*) in recent years has increased through-out the world [1]. Its cultivation is very essential for many sub-Saharan African countries in which agriculture continues to make significant contributions to Gross Domestic Product (GDP). Whether consumed fresh or in its processed form, a cup of raw cabbage nutritionally contains 93 % water and is a good source of dietary fiber as well as vitamins A and C [7]. Globally, cabbage is grown on over 4.83 million ha of land with over 69 million metric tons in harvest [8]. In Africa, cabbage remains a very important crop for smallholder farmers, providing income and

nutrition, and enabling small farms to remain financially viable, especially in the rapidly growing peri-urban farming sectors [9].

In Cameroon, agriculture and related employment together is the livelihood bedrock for more than half of the population, the majority of them located in rural areas. Smallholder (mostly rural) farms dominate agricultural production in the country. It is therefore expected that any significant growth in the agricultural sector should boost the rural economies, in particular, in order to have a meaningful impact on the wider economy. Cabbage cultivation in Cameroon is done mainly using conventional production methods consisting of applying costly inorganic chemicals which cause additional damages to the environment. In view of this, productivity increases, through efficient use of existing technology and resources, must be accorded all the seriousness that they deserve in the face of worsening climatic conditions, poor accessibility to agricultural inputs by smallholder farmers and environmental degradation that has become the bane of agriculture in most Sub-Saharan African countries such as Cameroon [10-12]. Therefore, the need to produce organic cabbage using sustainable agricultural techniques that are less costly and natural resources conserving, and causing little or no effect on human health cannot be over emphasised. Because of the fact that profitability is the most important factor for farmers [13-15], it is important to research and compare the productive and economic performances of organic and conventional farms.

The objective of this paper is therefore to analyze the economic and financial sustainability of organic and conventional (cabbage) cultivation in order to evaluate if nowadays, in a so dynamic and complex economic context, organic (cabbage) investment could sustain household livelihoods.

In most developing countries, current significant increases in crop yields up from the mid-1960s have been achieved thanks to intensification, resulting mainly from an unprecedented adoption and use of inorganic fertilizers stemming from heavy subsidy programs, after the commencement of the green revolution [12,15,16,]. Since then, chemical fertilizers have been considered a major driver for increased crop yields in such countries. Inorganic chemical fertilizer use therefore positively correlates with food security [17]. The inorganic fertilizer revolution has benefitted from favourable policies of national governments and the donor

community. This, however, is rapidly becoming unsustainable due to high costs and the inability of governments and donors to continue subsidizing inorganic fertilizers. In addition, governments worldwide are increasingly coming under pressure to promote organic agriculture, given the environmental benefits of organic practices [18]. Increasing numbers of consumers especially in developed countries recognize that organic products are healthier, safer and fairer alternatives to standard products, for which they are willing to pay a higher price [19,20]. In this line, a major challenge therefore for agriculture in the 21st century is to feed the world's growing population with little or no effects on the environment. For many African countries, the major challenge however remains how to adequately feed its ever growing population, and to what extent this can be achieved by switching to organic agriculture.

The organic agricultural sector in Cameroon for instance is still relatively underdeveloped, accounting for only 0.08% of total agricultural production [21]. There is still a huge potential for expansion. Over 60% of its population directly depends on subsistence agriculture for their livelihoods [22,23]. In total, about 51% live below the poverty line [24]. While the contribution of organic agriculture to ecological sustainability cannot be doubted, the question needs to be asked whether its promotion will enhance food security in an agriculture-dependent country like Cameroon. For a country that is still grappling with the problem of food insecurity (and at the same time is the bread basket for its neighbours), a policy shift towards organic agriculture should first and foremost be backed by economic competitiveness. After all, agriculture is said to be sustainable when it is economically viable, humanly (socially) acceptable and environmentally friendly [12,20, 25-27]. This paper therefore attempts to provide knowledge that maybe useful for policy makers in developing countries like Cameroon. It empirically compares sustainability aspects for conventional and organic agriculture. Such knowledge could also be useful for many agriculture-dependent countries in Africa and Asia.

2. CONVENTIONAL OR ORGANIC AGRICULTURE: WHICH WAY FORWARD?

By definition, conventional agriculture includes a plethora of intensive-type of farming practices

and methods, fundamentally based on high-input application systems for increased yields [28,29]. Organic agriculture refers to farming systems that enhance soil fertility by maximizing the efficient use of local resources, while foregoing the use of agrochemicals, genetically modified organisms and the many synthetic compounds used as food additives [30]. In spite of the increasing need for food as a result of the growing world population, environmental concerns are pressurizing agriculture to be sustainable, i.e. economically viable, but socially equitable and ecologically sustainable at the same time. Thus farming systems are to be designed in such a way that there are productive and the same time maintain or enhance the provisioning of ecosystem services (i.e., biodiversity, soil quality, nutrient management, water-holding capacity, control of weeds, diseases and pests, pollination services, carbon sequestration, energy efficiency and reducing global warming potential, as well as enhanced resistance and resilience to climate change and crop productivity) [29].

As population continues to increase worldwide, increasing food production to feed the growing population is also gaining importance. However, there is growing debate on whether to concentrate on farm practices that yield more but with higher damage to the soil and environment or those that yield less but with limited detrimental effects to the soil and the environment, or put simply, safe [30].

Organic agriculture is a quasi automatic winner in the debate. For instance while [31] mentioned that the cost of producing organic foodstuffs is more expensive due to high labor requirement which is relative higher than that of conventional production, its yields are generally 25% lower on average than that produced conventionally. Other studies for example [12,20,26] have shown that conventional agriculture uses land much more efficiently, providing a higher yield-output to human labor-input ratio than organic farming. More so, different integrated pest management (IPM) systems can be better used in conventional agriculture to control many persistent diseases [9]. But conventional agriculture is blamed for the currently high degradation rates of the planet's natural resources and increasing use of arable land for farming, with implications for sustainable natural resource management [32]. As the planet's ecosystems become increasingly compromised and inextricably linked to human health and well-

being [33], resource-intensive inorganic agricultural practices are being put to question. For instance, crop irrigation is increasingly associated with freshwater scarcity [34]. Genetically modified (GM) crops are blamed for ecosystem ill health and the difficulty in preserving genetic diversity [33,35]. Conventional agriculture which generally has more economic benefits than the sustainable (organic) agriculture in a short run [11,36] is accused of intensifying energy use and increasing unemployment through mechanization [37]. Its threats to the environment, local ecosystems, animals and human beings have been frequently atoned [12,38].

Organic farming is therefore frequently portrayed as a holistic production approach (for crops and livestock) where the use of environmentally friendly production processes (cultural, biological and mechanical methods) lowers carbon foot prints, reduces environmental impacts as well as renewable sources [25,26,39].

Perhaps, and even more important in this debate, is the dichotomy that exists between the narratives from the developed and developing worlds. In most developed countries, usually less than 10 percent of the population depends on agriculture for livelihoods [40]. In many developing countries, this percentage is usually above 40 percent. The advancement of science in many developed countries also allows higher production to be realized on organic farms, than in many developing countries. Thus while issues of environmentally friendly agriculture dominate the policy environment in many developed countries, the issue in developing countries is still food security. It therefore becomes important to assess which approach will be best suited under which conditions.

In spite of growing global concerns about the nexus between agriculture and the environment, food security-related frameworks in Cameroon for instance are still largely focused on narrowing existing crop yield gaps [41]. Meanwhile, timid research on the subject has largely demonstrated the important contribution of organic agriculture to increases in total soil nitrogen and organic matter content in general [42]. Its adoption remains slow, especially amongst households with perpetual or sporadic labor shortages [43]. Given the fact that over 60% of all households in the country depend on agriculture, the Cameroon government is likely to support agricultural practices that are principally

capable of reducing food insecurity as rapidly as possible. In the best scenario, such systems should be economically viable and environmentally friendly.

We attempt to contribute to this discourse by assessing the economic and environmental viabilities of conventionally and organically produced cabbages in Cameroon.

3. MATERIALS AND METHODS

3.1 Description of the Study Site

This study was conducted at the training center of agriculture at Noun (CEFAN¹) located in the Noun division in Fouban in the West Region of Cameroon; between latitude 5°44' 48" north and 1° longitude 0°53' 33" East of the equator, at an elevation of 1179 MASL. Fouban has a population of 92,673 making it the 4th biggest city in Cameroon's Western Region [44].

In general the climate of the Noun division is a tropical one with a long rainy season ranging from March to October and a short dry season ranging from November to February (precipitation rate averaging 1900 mm). Mean temperature in the area varies between 21°C and 23°C.

Created in August 1990, CEFAN Noun is the fruit of reflection, and critical thought of catholic missionaries to ameliorate the economic and social conditions of youths in Noun division [44]. The choice of the site was therefore strategic, given the possibility of disseminating results locally.

3.2 Research design

The experimental plot was purposefully selected based on the following characteristics: the field had not been farmed for three years, it was well drained, free from water logging and received proper sunlight, located near a source of water, and well protected from domestic and wild animals. This study adopted an experimental design. A randomized complete block design was used. 10 equal plots (5 plots each of 20 M² for conventional and organic cabbage production) were randomly selected to host same initial number of plants.

A nursery was first established where cabbage seeds were nursed and nurtured on flat garden beds for transplanting on the experimental plots. The seedlings used for both the conventional and non-conventional trials were obtained from the same seed beds. The seedbeds were initially prepared using a prepared soil mixture in the ratio of 1:1:1 of soil, sand and well decomposed farm yard manure (FYM). The nursery beds were raised 15 to 20 cm high from the ground level and spaced 30 – 40 cm. Seeds were sown at a 1.0 cm depth and then covered with the soil mixture. At the end, the seed beds were covered with a small layer of mulch in order to maintain soil moisture. Watering was done on the nursery 2 times a day (in the morning and in the evening) for 4 weeks when seedlings were ready for transplanting. While still in the nursery, fungicide and insecticide treatments were applied two times a week at an interval of 3 days.

10 experimental plots of 20 M² each were used for the entire experiment (5 plots for conventional 5 for organic cabbage farming respectively). Same land preparation practices were applied on all the plots. 250 g of poultry manure was applied into the spots for both conventional as well as the organic cabbages and mixed well with soil, watered for 4 days before out-planting of seedlings. Poultry manure from the same source was used for both conventional and organic cabbages to insure same nutritional content. Seedlings were then randomly collected from the nursery and transplanted in to all the plots on the same day. Before transplanting, seedlings were amply watered in the morning. Similar planting distances were maintained for all the plots. The major difference between conventional and organic plots was therefore the application of synthetic pesticides on the former and the application of organic pesticides on the latter plots. A total of 625 seedlings were planted in each of the trials.

The organic plots received a weekly application of organic pesticides using a Knap sack sprayer consisting of 1 L of water to 65 ml of an organic mixture of soap and kerosene and the liquid organic fertilizer (AGRODYKE (1-3-1)). On the other hand, the conventional plots received on a weekly basis, a dosage of inorganic pesticides consisting of 1L of water diluted in 38 g of synthetic fungicide (MONCHAMP), 10 ml of insecticide (KUNFU) and 10 g of the chemical fertilizer (AFCOTT (20-10-10)) applied as specified by the manufacturing company. This was done once a week for 2 months before the

¹ Centre de Formation Agricole du Noun

plants were harvested from the trial plots. Applications were done on the different (conventional and organic plots) on the same days, using the various specifications. Weeding was done on all plots once in 2 weeks, on the same days.

Weekly measurements were taken from 150 randomly selected cabbage plants (i.e. 15 per plot) on plant growth parameters such as the height and leaf surface area, plant growth and survival rates. Polythene bags were used to collect soil samples before and after the experiment for pH analysis. All recordings were written in a well calibrated log book and an exact duplicate in a separate book.

All the cabbages were harvested after the 10th week. No spraying was done in the last week towards harvesting to respect the waiting time of the chemicals. Cabbages were sold in the two different groups and the sales amounts recorded for use in the economic analysis.

The entire field experiment lasted for 10 weeks.

The collected data was analyzed using SPSS (Statistical Package for Social Sciences) version 20.0, as well as the Microsoft excel 2010. Some key results are presented and discussed in the next section.

4. RESULTS AND DISCUSSION

In this section, some results from conventional and organically cultivated cabbage plots shall be presented and discussed. Results for growth parameters such as plant heights, mean plant leaf surface area, survival rate as well as the yields will first be presented as proxies for economic sustainability of conventionally and organically produced cabbage. The surviving plants are then used to estimate the economic value of the plants. The soil pH will be used to proxy their contributions to ecological sustainability.

4.1 Economic Sustainability

4.1.1 Plant characteristics

Results of mean plant heights and leaf surface area over the 10 week period are presented on Fig. 1. As observed in Fig. 1, there was a general increase in the mean plant height as well as the mean leaf surface area among all the cabbage plants over the 10 week experimental period. For instance it is observed that while the mean plant

height after 1 week was 13 cm and increased continuously to 33 cm at week 10, the mean leaf surface area was 6 cm² after 1 week and also increased continuously to 68 cm² after 10 weeks. However, detail results show that the mean plant height is greater than the mean leaf surface area during the first two weeks. This is probably because of the plant morphology and physiology which usually starts with small numbers of leaves and sizes, which will then grow gradually in concentric circles forming a head of cabbage. In the third week, the mean plant height and the mean leaf surface area were observed to be the same, probably as a result of fertilizer application that had taken place, enabling the plant mean leaf surface to grow. Rapid photosynthesis due to increased intensity of sunlight and the amount of plant nutrients found in the soil could have led to a corresponding increase in the cabbage size. From the 4th to the 10th week, the plant mean leaf surface area is greater than the plant mean height. This is due to the fact that as from the 4th week, the cabbage plant responds more to the leaf growth as it starts to form concentric circles resulting in an increase in the surface area of the outer leaves. From this stage the plant grows more when fertilizer is applied. Thus we can conclude that cabbage growth is influenced by morphological and physiological factors inherent to the plant as well as the fertilizer and pesticides applied.

A correlation analysis between the mean leaf surface area and the mean plant height over the 10 week period showed a very strong positively significant relationship between plant height and leaf surface area ($r=0.97$, $p=0.00$, 2-tailed). Therefore the plant height increases with increasing leaf surface area. A comparative analysis was done on the parameters of conventional and organic farm practices. The comparative analysis of the plant height and leaf surface area for the conventional and organic farm practices are presented in figures 2 and 3 below. The increase in plant height between week 2 and 3 was only 1cm, while that of week 3 and 4 was observed to be 3 cm. The 2 cm increases in the mean plant height for the organically produced cabbage is probably due to the weekly application of liquid organic fertilizers (10 L per 50 plants) which favoured the constant growth in plant height.

In conclusion, the average plant height of the conventionally produced cabbage is greater than the mean plant height of the organically

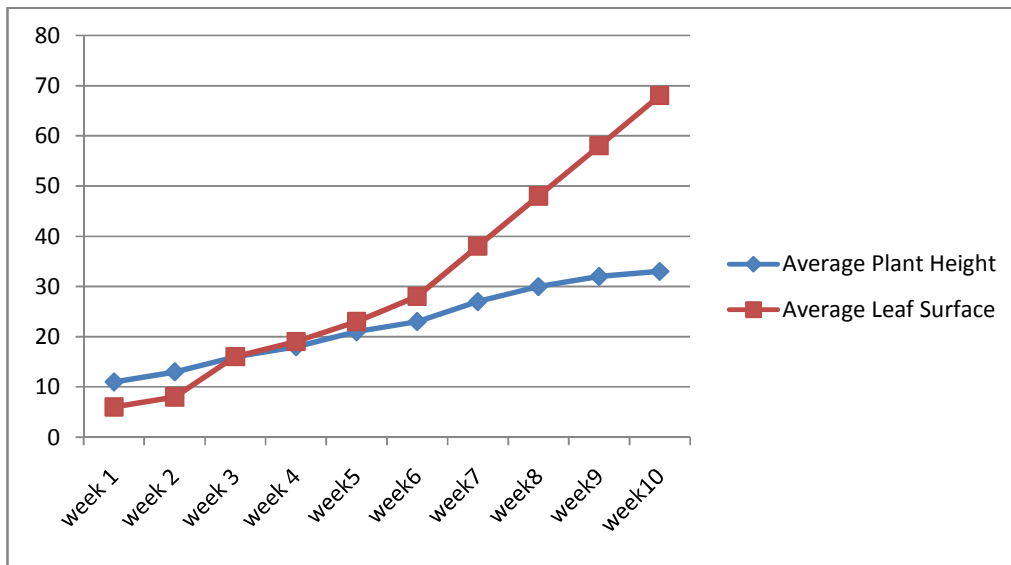


Fig. 1. General pattern of plant height and surface area for all observed plants

Source: Field data analysis

produced cabbage after the 10 week experimental period. This higher plant height for conventionally cultivated cabbage was probably caused by the fertilization of the farm with chemical fertilizer (NPK 20-10-10), as chemical fertilizers are more adapted with the specific needs of the plants than organic fertilizers. The 4 cm increase in plant height week 7 was probably due to a change in the quantity of fertilizer applied the previous week (20 g / plant) resulting to a double increase in the cabbage height. However, this fertilizer application was quickly controlled and the plants' growth rate was also quickly restored to its normal rate of 3 cm the next week and to 2 cm two weeks later.

In summary, we can conclude based on the results from Fig. 2 that the average plant height of conventionally produced cabbage is higher than the average plant height of organically produced cabbage. Based on this conclusion, we can hypothesize that the cabbage height of conventionally produced cabbage plants will increase proportionately with the quantity of fertilizer applied up to a point where it becomes static and reduces due to maturity. On the other hand, the height of organically produced cabbage plants depends largely not just on fertilizer application but also on pest control. This conclusion is in line with that of [4] who showed that organic fertilizer plays a vital role in cabbage, increasing the plant growth but takes a longer time to build up in the soil and hence being assimilated by cabbage plants while

chemical fertilizers on the other hand are directly assimilated by cabbage plants. If this contention is true, then conventional cabbage production should be more profitable than its organic counterpart.

Fig. 3 allows us to infer that the average leaf surface areas for both conventional and organic cabbages are almost the same for weeks 1 and 2 (6 cm² and 8 cm² respectively). From the 3rd week, the average leaf surface area for both conventional and organic cabbages increases continuously on a weekly basis. This is probably due to the application of fertilizer during the 2nd week. From the 6th to the 10th week, there was a 10 cm² increase in the average leaf surface areas for the conventionally produced cabbages, resulting from fact that the quantity of fertilizer applied to the plants was doubled at the 6th week (20 g per plant). This 10 cm² for the organically produced cabbages was observed between weeks 8 and 10. We can therefore conclude that the mean leaf surface area of cabbage plants increases with increase application of fertiliser and is higher with conventional agriculture than with organic agriculture. However, it is worth mentioning that the mean leaf surface area can also be influenced by the plant density. Our results are in line with that of [45,46], who hold that the average ratio of organic-to-conventional yield was, 0.75, indicating that overall organic yields are 25% lower than conventional yields [see also 20]. These differences in yields can be partly explained by differences in the inputs of

nutrients such as nitrogen and phosphorus. Conventional agriculture uses fertilizers that contain these nutrients in a form that can be taken up directly by the crop, whereas the release of plant-available nitrogen from organic sources such as compost or animal manure is slow and often does not keep up with demand during the peak growing period. This probably explains why organic farming of cereals and vegetables for example have significantly lower yields than their conventional counterparts (26% and 33% less respectively), indicating that chemical fertilizers are more adapted to plants' specific nutrient uptake [46].

The survival rate of plants in conventional and organic cabbage plots over the 10 week period is presented in Table 1. As can be seen, there is a reduction in the percentage of grown plants of 5% and 8% in the second week for conventional and organic cabbages respectively. This is probably due to the transplanting of the cabbage plants from the nursery beds in to the experimental plots that occurred at the first week. During the transplanting exercise, each plant experienced stress that affects its adaptability and hence its growth potentials. Consequently, those plants that are not strong enough could die off. At some stage of the experiment (between weeks 4 and 6) when the plants were already adapted to their living

medium and positively responding to treatments, the percentage of grown plants for both the conventional and the organic cabbage production stabilized. However at the 7th week when mulching took place, some plants were destroyed. This probably explains why [44] in their work in Switzerland explained that the efficient and careful use of inputs by farmers can properly cause an increase in the output of vegetables such as cabbages.

Recall from Table 1 that 551 and 542 plants respectively survived in the conventional and organic farming plots respectively. However, while 95% matured to cabbage heads in the conventional plots, only 80% matured to cabbage heads in the organic plot (see Table 2). This result therefore suggests that the yield of organic cabbages is significantly lower than the conventional one ($X^2=.05$). This result is in line with [43] who reports an average ratio of organic-to-conventional yield of 0.75. [20] also found a 21% difference in their study in Sicilian lemon Orchards. More so, population growth and increasing consumption of calorie- and meat-intensive diets are expected to double human food demand by 2050. Therefore, conventional agriculture is a preferred alternative to organic agriculture, if one prioritizes the food needs of the growing population, trading off the environmental damages that go with it.

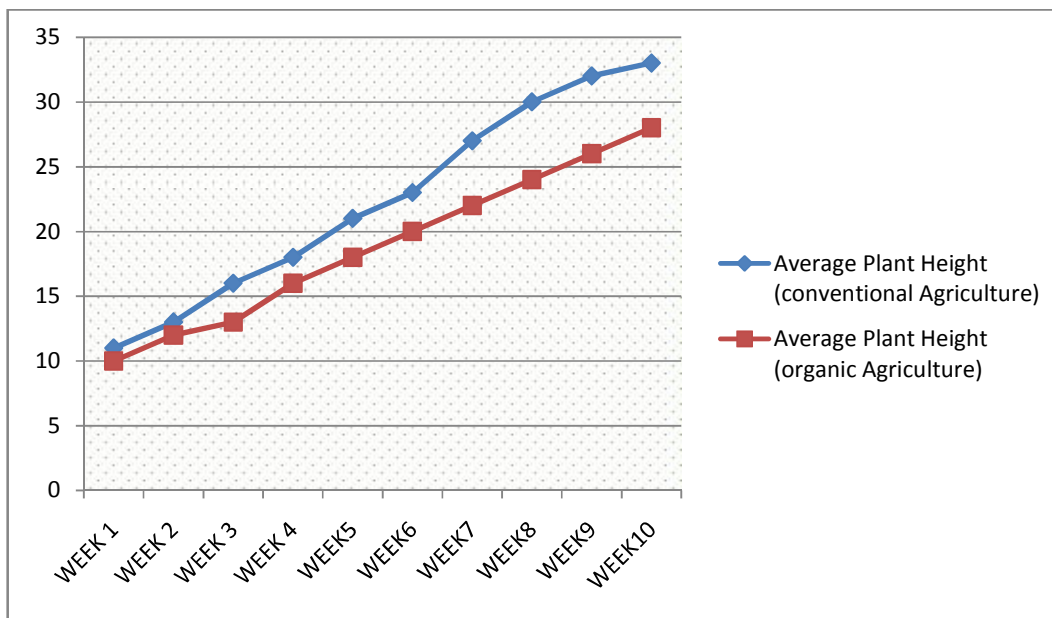


Fig. 2. Average plant heights for conventional and organic cabbage production

Source: Field data analysis

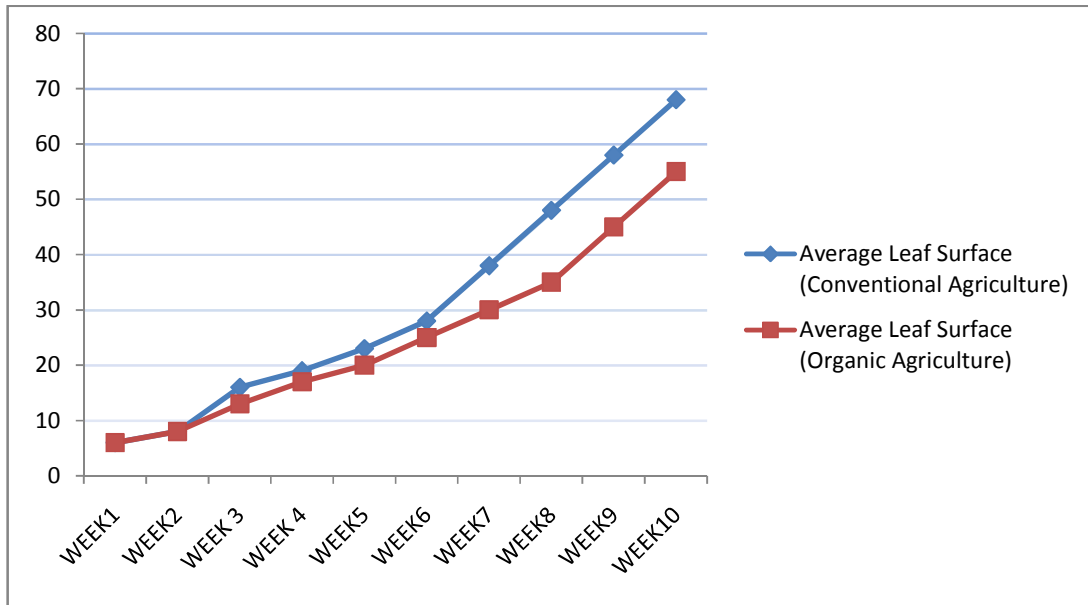


Fig. 3. Average plant leaf surface by agriculture type
 Source: Field data analysis

Table 1. Surviving plants by agriculture type and week

Weeks	Agriculture type	Plants grown	Percentage
Week 1	Conventional	625	100%
	Organic	625	100%
Week 2	Conventional	594	95%
	Organic	575	92%
Week 3	Conventional	582	93%
	Organic	569	91%
Week 4	Conventional	582	93%
	Organic	563	90%
Week 5	Conventional	581	92.9%
	Organic	563	90%
Week 6	Conventional	580	92.8%
	Organic	563	90%
Week 7	Conventional	552	88.3%
	Organic	547	87.5%
Week 8	Conventional	551	88.3%
	Organic	544	87.1%
Week 9	Conventional	551	88.3%
	Organic	543	87%
Week 10	Conventional	551	88.2%
	Organic	542	86.7%

Source: Field data analysis

4.1.2 Comparative gross margin analysis

Recall from Table 1 that 551 and 542 plants respectively survived in the conventional and organic farming plots respectively. However, 95% of cabbages of conventional plots survived till full maturity, compared to only 80% from the

organic plots. Assuming similar sized cabbage heads, the yield of organic cabbage will be 15% (and significantly) lower than that of conventional cabbage ($X^2 = 0.05$).

To complete the economic analysis, we apply the gross margin approach to compare the total

production expenditures with the expected income from sales of crops from the experimental plots. The Gross margin was calculated as follows:

$$\text{Gross Margin} = \text{Gross Output} - \text{Variable Costs (1)}$$

The gross output was calculated by multiplying the total number of cabbage heads from each agricultural type by FCFA 150². All the inputs for the different plots constituted the variable costs. We then extrapolated this result to obtain the estimated Gross Margin from one hectare of cultivation, for both the conventional and organic agriculture. The results are presented in Table 2.

Notes:

1. This analysis does not take into account the cost of labor, which in any case will be slightly higher for organically produced cabbages. It has also considered only one crop cycle.
2. The selling price is similar, given that there is no separate market for organic products in Cameroon.
3. 1USD ≈ FCFA 535

The gross margin analysis suggests that conventional cabbage production is more lucrative than organic cabbage production, with a difference of ≈FCFA 1 Million (≈2000 USD) per hectare. Results are similar to that of [11] who showed that gross production and profitability of conventionally produced crops is significantly higher than for organic ones [see also 25,26,27]. This result however contradicts [20] who observed that organically produced lemon had higher profitability than conventionally produced lemons in Sicilia despite the higher yield of the latter (+21%) per hectare. They attributed this higher profitability to higher price for organic lemon in the market which was guaranteed by certification [see also 12 for similar results].

4.2 Environmental Sustainability

Given the limitations of time, technology and infrastructure, the environmental sustainability could only be estimated by changes in pH. It was

² It is worth mentioning that organic cabbages are generally not differentiated on the local markets in Cameroon and therefore do not attract higher prices as maybe the case in other countries. The average price of FCFA 150 was obtained from the local Foubam market, where the cabbages were to be eventually sold.

observed that the cabbage production activity reduces the soil pH in both plots, irrespective of agriculture type (Table 3), with a slightly lower change on average in the conventional plots. In the conventional plots, the inorganic fertilizer used was directly assimilated by the plants and the remaining soil nutrients probably leached. The inorganic fertilizer could also have contributed to acidifying the soil. On the other hand, the organic cabbage production in which poultry manure and AGRODYKE were used probably took more time for nutrient assimilation by the plants. Consequently, a great quantity of the organic fertilizer remained in the soil resulting in only a slight reduction of the soil pH. [47] in his work in Washington DC also found out that soil quality is affected by the type of farming activity being carried out. He mentioned that in conventionally managed fields, one would find more degraded and low quality soils (less soil organic matter, fewer annelids, lower soil pH and salinity, lower soil moisture, lower levels of nitrogen, phosphorus, and potassium, increased compaction and lower water infiltration rates) as compared to organically managed fields. Such factors would reduce the farm’s ability to respond to drought conditions, allow topsoil erosion, and result in an increased loss of soil. The results showed that, in terms of soil quality, soil organic matter and annelids content, conventional farms were significantly lower. [48] on his part mentioned that excessive soil fertilization may lead to soil being polluted, particularly with high level of sodium and potassium containing fertilizers. As explained by him, this has negative impacts for instance on soil pH, soil structure deterioration and the increasing feature of acid irrigation. Due to poor infrastructure, we could not perform any soil analysis beyond pH measures.

Table 2. Gross margin analysis of conventional and organic cabbage production

Costs	Agriculture type	Mean per Hectare (FCFA)
Total variable costs	Conventional	4,009,500
	organic	3,561,500
Total gross output	Conventional	7,860,000
	organic	6,510,000
Gross margin	Conventional	3,850,500
	organic	2,948,500
	Difference	(p=0.04)
	(FCFA):	
	902,000	

Source: Field data analysis

Table 3. Evolution of soil pH values under conventional and organic agriculture

Conventional cabbage production		Organic cabbage production	
PH before the experiment	PH after the experiment	PH before the experiment	PH after the experiment
6.9	6.3	6.9	6.7

Source: Field data analysis

Based the above results, we contend that the long term application of conventional agriculture is likely to render soils acidic at higher rates than organic agriculture.

5. CONCLUSION

Recent global developments have stimulated increasing interest and drift towards sustainability paradigms. In this light, the concept of “sustainable” farming systems is gaining vast grounds in the agricultural sector. Logically, this narrative has been dominated by the developed countries, where food insecurity issues are generally irrelevant. In many developing countries where food security is often a key policy objective, caution is being demonstrated to adopt agricultural practices on the sole basis of environmental sustainability. Adopting agricultural practices must also be guided by their ability to better and quickly enhance food security and economic growth. The study contributes to this literature, by analyzing economic and environmental sustainability of conventional and organic agriculture in Cameroon, using the common cabbage, *Brassica oleracea L. var. capitata*. The study applied the randomized complete block design to establish 5 replications each of plots under conventional and organic agricultural practices. The plots of both treatments were monitored for 10 weeks during which data on the leaf surface area, plant height and survival rate (yield) for the plants and soil pH in each plot was collected. pH values were also measured, Gross margin was used to perform the final economic analysis, while the ecological sustainability was proxied by changes in soil pH. Analyzing the results led us to a number of conclusions.

First, conventional cabbage production was more economically viable than its organic counterpart. The gross margin analysis indicated better returns of about FCFA 1 million (≈2000 USD) per hectare in conventional compared to organic cabbage production. This was based on the assumption that organic cabbages sell at similar prices as conventional ones, since there is little

or no market segmentation in Cameroon along production type.

Secondly, organic cabbage production had only a slight impact on the environment, as it caused lowered changes in soil pH compared to conventional agriculture.

Based on these results obtained from cabbage production in Cameroon, we recommend conventional agricultural practices as a preferred practice and a rational choice, when (1) food security poses a significant threat to human survival; and (2) organic product markets are underdeveloped. These two characteristics still largely dominate many developing economies. However, efforts could be made to move towards integrating conventional and organic farming practices, in order to make minimal gains towards environmental sustainability. Safe food production as atoned for instance by [49] will equally pay attention to the economic dimension. Further research is however necessary, to avoid a cut-and-paste approach in favor of organic agriculture (exemplified in this case by cabbage production), which could dampen ongoing efforts towards food security in many developing countries, such as Cameroon.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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