

Sustainable Vs. Conventional Agriculture

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Abstract - This paper will analyze and compare two types of farming, organic and conventional. In a comparison of agriculture, my goal is to assess the impact and performance of each practice and then identify the best method for growing crops. Although there are many types of agricultural practices, they can be generalized as sustainable or conventional based on the techniques used. Sustainable / organic farming aims to produce a number of crops, without the use of synthetic chemicals or fertilizers, while enhancing soil composition and promoting biodiversity. This is a traditional, more permanent type of farming that relies on ecosystem services to maintain the integrity of the landscape while still producing sufficient yields. Conventional farming uses synthetic chemicals and fertilizers to maximize the yield of a particular crop or set of crops, which are typically genetically modified. This method requires a significant amount of chemical and energy input and weakens the ecology of a landscape. In a comparative analysis of these two techniques, it is important to highlight the fact that the crops studied differed in soil composition, geography, and rotation systems. "To carry on extensive long-term trials for a number of crops in several different geographical areas would be of fundamental importance to understand the potential of organic farming as well as to improve farming techniques in general." (Gomiero, Pimentel, and Paoletti 2011). Due to the many different factors determining crop health and productivity, there is a need for much more extensive research on the subject. Therefore, my goal in writing this paper was to use reliable, long-term research that made specific assessments of the two generalized types of farming and then compare the results.

Keywords - Agriculture, Conventional Agriculture, Farming, Sustainable etc

I. Introduction

Farming has enabled human populations to dominate the world's landscapes for many thousands of years. The science of agriculture has been refined and perfected over time to accommodate for the ever-increasing human population. Until recent centuries, productive crops were mostly organic and existed with some permanence as part of a landscape. As communities grow though, less and less land is available for food production and existing crops become easily exhausted. Food insecurity caused by rapid population growth has pressured science to step in and produce many synthetic chemicals and gene manipulation techniques to maximize the potential of plants. In addition, agricultural production has increased tremendously worldwide over the last century. Coupled with this growth however is the pollution and degradation of the natural environment. Many agricultural techniques exist today, but in an effort to adjust to the exponential trends of our population without compromising the integrity of the environment it is necessary to have a global transition towards sustainable farming. With the current population at seven billion and rising, an important question must be addressed: What is the most sustainable and cost effective way to feed the world's population? Fortunately humans have been perfecting agricultural methods for thousands of years, which can help to answer this question.

II. History of Agriculture

Agriculture has played a tremendous role in the advancement of human society. Agriculture has been around since roughly 10,000 B.C.E. and has enabled humans to manipulate ecosystems and maximize population growth (Xtimeline.com). The science has encouraged people to live and develop rich, permanent settlements all over the world. When humans first discovered the potential of planting seeds, they suddenly had the ability to explore the world and establish infrastructures wherever soils were fertile.

Soon after the start of agriculture people began to select for genes that maximized plant yields. Selective breeding was first implemented on plants over 10,000 years ago to produce desired characteristics in crops (USDA.gov). This discovery further contributed to the permanence and size of settlements. With breakthroughs in agriculture, populations increased and development spread.

Early farming techniques depended on local climate conditions, but most farmers would continue to plant on the same field year-after-year until the soils were exhausted of nutrients. This encouraged ingenuities such as crop rotation and intercropping (Economywatch.com). Intercropping is a technique in which a variety of crops are grown together, creating a microclimate that favors the survival of each plant, maximizes potential yields and maintains soil fertility (Archaeology.about.com). For example, Native Americans developed an intercropping technique over 5,000 years ago called the three sisters, where maize, beans, and squash were grown together (Archaeology.about.com). Maize consumes a lot of nitrogen, while beans supply nitrogen to the soil, and squash benefits from a shady, moist climate. Intercropping is one of many early discoveries in agriculture still being implemented today that promotes biodiversity, maintains soil composition, and fortifies plant health. Techniques such as irrigation, intercropping, and crop rotation have progressively increased efficiency in agriculture. Over the last few centuries however, radical changes have been made in farming and many countries have made a shift toward conventional methods. Factors such as growing populations, economic instability, climate change, and pressures from companies to produce higher

yields have contributed to this shift. However, adopting these conventional methods subjects farmers to the greed of industry, as their crops depend on a high input of energy, synthetic chemicals, and genetically modified organisms. And once committed to the conventional practices, farmers find themselves locked in a perpetual cycle of loans, subsidies, and debt.

III. Conventional Agriculture

Conventional agriculture is a broad term that has a number of definitions, but 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. “This method usually alters the natural environment, deteriorates soil quality, and eliminates biodiversity.” (USDA.gov). 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. In maintaining a conventional system, biodiversity, soil fertility, and ecosystems health are compromised (Huntley, Collins, and Swisher). Production of these crops is beneficial to nothing but food security and economy. Once established, a conventional farm requires constant maintenance but produces maximal yields.

Maintenance is made easy for farmers as conventional farming typically involves monocropping, but is also very expensive. In a conventional system farmers will designate entire fields to just one crop, which creates uniformity. Uniformity can determine both the success and failure of conventional systems. A uniform crop is ideal because it reduces labor costs and makes harvesting easy, but it can also impact biodiversity and make crops susceptible to pathogens (Gabriel, Salt, Kunin, and Benton 2013). Chemicals and genetically modified organisms make maintenance of conventional systems relatively simple for farmers, but require a constant input of energy and money. In a conventional system, farmers can apply pesticides and herbicides to crops at a much more efficient rate if they are made up of just one type of plant, but this has a number of unintended consequences. Since the goal of conventional agriculture is to maximize yields, environmental health and biodiversity are usually not preserved.

IV. Sustainable Agriculture

Where conventional farming represents one extreme of agriculture, sustainable farming represents the other. “Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.” (Gomiero, Pimentel, and Paoletti 2011). Sustainable agriculture is a more holistic approach to farming than conventional in that it relies on ecosystem services and is typically much less detrimental to the surrounding landscape. Sustainable agriculture is a natural way to produce food and has a number of social, economic, and environmental benefits.

There are many types of sustainable farming that all rely on natural cycles to ensure plant health and crop performance. Sustainable farming forgoes the use of synthetic pesticides, herbicides, and fertilizers to produce food. Instead, farmers will plant a variety of plants together to promote biodiversity and ward off pests and pathogens (Nicholls and Altieri 2012). Where conventional systems promote uniformity and depend on synthetic chemicals for protection against disease and pests, sustainable systems rely on biodiversity as a measure to protect against these things.

Sustainable agriculture profits farmers, economies, and food banks while existing symbiotically with the landscape. One example of many in sustainable farming practices, which emphasizes economic benefits and environmental health, is conservation agriculture. “By increasing soil organic matter contents and moisture-holding capacity, CA can double subsistence crop yields in areas where use of fertilizers is uneconomic and it can sustain production in years with low rainfall.” (Kassam and Brammer 2013). Conservation agriculture underlines the focus of sustainable agriculture in that it focuses on producing high yields without compromising the integrity of the environment.

V. A Comparison of Agriculture

In a comparison of conventional and sustainable agriculture there should be several points of focus: production, biodiversity, soil composition / erosion, water use, energy use, and greenhouse gas emissions. The environmental impact and production levels of each method will determine its overall viability as a solution to growing trends. It is necessary to make these comparisons in order to identify the best agricultural method that can sustainably meet the needs of the current population. Although these comparisons are based off of scientific data, there is much more research that needs to be done in order to make a definitive judgment.

To meet the needs of the current population requires a tremendous amount of resources. Not taking into account the environmental damage associated with intense production, conventional agriculture is a feasible way to provide for more people; “population growth and increasing consumption of calorie- and meat-intensive diets are expected to roughly double human food demand by 2050.” (Mueller, Gerber, Johnston, Ray, Ramankutty, and Foley 2012). In addressing this rapid growth, production levels become a serious point of comparison. “Organic yields are globally on average 25% lower than conventional yields according to a recent meta-analysis, although this varies with crop types and species and depends on the comparability of farming systems.” (Gabriel, Salt, Kunin, and Benton 2013). Most research indicates that sustainable crops produce much less than conventional systems.

There are many environmental benefits associated with sustainable agriculture, but its production capacity is limited. In general, sustainable agriculture fails to match up to conventional agriculture in terms of production. This result varies though, and in some instances organic crops actually best conventional crops. For example, under drought conditions organic crops tend to produce higher yields because they typically retain more water; “As part of the Rodale Institute Farming System Trial (from 1981 to 2002), Pimentel et al., (2005) found that during 1999, a year of extreme drought, (with total rainfall between April and August of 224 mm, compared with an average of 500 mm) the organic animal system had significantly higher corn yield (1,511 kg per ha)

than either organic legume (412 kg per ha) or the conventional (1,100 kg per ha).” (Gomiero, Pimentel, and Paoletti 2011). Although certain conditions may favor organic crops, conventional agriculture is designed to produce the highest yields possible. Many factors contribute to this difference in production. Conventional crops are designed specifically to produce maximal yields; therefore, the difference should be expected. Typically conventional crops are genetically modified to perform better under certain conditions than sustainable crops (Carpenter 2011). However, these crops are also sprayed with toxic pesticides and herbicides to make up for their uniformity. Some research has been done to determine whether increased biodiversity is related to increased yields; “...farmland biodiversity is typically negatively related to crop yield; generally, organic farming per se does not have an effect other than via reducing yields and therefore increasing biodiversity.” (Gabriel, Salt, Kunin, and Benton 2013). Although levels of production are reduced in sustainable agriculture, studies show that higher levels of biodiversity are linked to healthier crops.

Biodiversity plays a large part in this comparison because it is a determinant of agricultural health and performance. The greater the biodiversity, the more immune plants are to pests and disease (Gomiero, Pimentel, and Paoletti 2011). This is important to highlight because conventional agriculture discourages biodiversity and instead relies on synthetic chemicals to maintain crop health. Over 940 million pounds of pesticides are being applied annually with only 10% of that reaching the desired target, a number that could be greatly reduced if conventional agriculture were to implement sustainable alternatives (Sustainablelafayette.org). Techniques such as integrated pest management and intercropping could be applied to conventional systems and in turn promote biodiversity.

High biodiversity is important to sustainable farming because it enhances the performance of the ecological cycles that the crops depend upon. Organic agricultural systems are typically much more rich in nutrients and diverse in organisms than conventional systems; “organic farming is usually associated with a significantly higher level of biological activity, represented by bacteria, fungi, springtails, mites and earthworms, due to its versatile crop rotations, reduced applications of nutrients, and the ban on pesticides.” (Gomiero, Pimentel, and Paoletti 2011). It is important to encourage high nutrient levels and biodiversity as these two factors contribute significantly to the health of the crops and the landscape. Although biodiversity does not directly determine crop yield, it does play a major role in the health and permanence of sustainable farms.

Despite the impacts conventional methods have on agricultural land, not all conventional farms degrade biodiversity. In fact, there are many ways farmers can reduce the amount of chemicals and energy they use by implementing low input alternatives; “Overall, the review finds that currently commercialized GM crops have reduced the impacts of agriculture on biodiversity, through enhanced adoption of conservation tillage practices, reduction of insecticide use and use of more environmentally benign herbicides and increasing yields to alleviate pressure to convert additional land into agricultural use.” (Carpenter 2011). The global impact agriculture has can be significantly reduced if conventional farmers adopt sustainable techniques.

In addition to higher levels of biodiversity, sustainable farming is typically associated with better soil quality. Organic farms have stronger soil ecology because they promote biodiversity rather than uniformity; “The results confirm that higher levels of total and organic C, total N and soluble organic C are observed in all of the organic soil.” (Wang, Li, and Fan 2012). The increased concentrations of these nutrients can be contributed to the depth of the food web and amount of biomass in sustainable systems. “In a seven-year experiment in Italy, Marinari et al. (2006) compared two adjacent farms, one organic and one conventional, and found that the fields under organic management showed significantly better soil nutritional and microbiological conditions; with an increased level of total nitrogen, nitrate and available phosphorus, and an increased microbial biomass content, and enzymatic activities.” (Gomiero, Pimentel, and Paoletti 2011). Sustainable crops are more permanent than conventional crops because they work in harmony with the landscape rather than drain it of nutrients and biomass.

Soil management is vital for existing farms because agricultural production is increasing globally and land is becoming less available to accommodate this growth. Conventional systems can improve soil quality by practicing sustainable methods like no-tillage farming, agro-forestry, and integrated pest management, but sustainable agriculture is the most effective form of food production in terms of maintaining soil conditions. “Establishing trees on agricultural land can help to mitigate many of the negative impacts of agriculture, for example by regulating soil, water and air quality, supporting biodiversity, reducing inputs by natural regulation of pests and more efficient nutrient cycling, and by modifying local and global climates.” (Smith, Pearce, and Wolfe 2012). Again, research shows that an increase in biodiversity and a reduction of chemical input can result in conventional farms with more healthy soils and improved crop performance.

A major problem concerning agriculture is soil erosion caused by nutrient loss, run-off, salinity, and drought. Soil erosion presents a threat to the growth of agriculture because, “Intensive farming exacerbates these phenomena, which are threatening the future sustainability of crop production on a global scale, especially under extreme climatic events such as droughts.” (Gomiero, Pimentel, and Paoletti 2011). Organic systems enhance soil composition as well as prevent soil erosion due to the greater amount of plant material and biomass in the soil. Conventional systems manipulate the landscape rather than adapt to it; “...soils under organic management showed <75% soil loss compared to the maximum tolerance value in the region (the maximum rate of soil erosion that can occur without compromising long-term crop productivity or environmental quality –11.2 t ha⁻¹ yr⁻¹), while in conventional soil a rate of soil loss three times the maximum tolerance value was recorded.” (Gomiero, Pimentel, and Paoletti 2011). Compared to sustainable farming, conventional crops are terribly inefficient at maintaining the integrity of agricultural landscapes. Conventional agriculture is therefore unable meet the demands of the growing populations without consuming a substantial amount of land and non-renewable resources.

On a global scale, water is a renewable resource that can meet the needs of our current population. Locally, however, water is a scarce resource and must be appropriated efficiently. The amount of fresh water available for consumption globally is small, but regional constraints make accessing that water even more difficult for many millions of people. Agriculture accounts for

approximately 70% of water use worldwide (USDA.gov). Increasing demand for fresh water is pressuring global stocks. To conserve this resource a drastic overhaul of water saving techniques, especially in agriculture, must occur.

Due to the abundance of flora and fauna in sustainable systems, organic soil typically retains much more water than conventional soil. This increased retention rate enables sustainable agricultural systems to produce much higher yields than conventional systems during drought conditions (Gomiero, Pimentel, and Paoletti 2011). This is a desirable characteristic in agricultural land as it allows crops to be more tolerable to changing climate. “In heavy loess soils in a temperate climate in Switzerland water holding capacity was reported being 20 to 40% higher in organically managed soils than in conventional ones... The primary reason for higher yield in organic crops is thought to be due to the higher water-holding capacity of the soils under organic management.” (Gomiero, Pimentel, and Paoletti 2011). To manage available water resources, sustainable agriculture is the more efficient approach to feeding the world.

A gap exists between current production rates and potential production rates of crops. Through better management of water and soil, much greater yields can be produced. Increasing efficiency to 100% is not entirely feasible, but implementing sustainable farming techniques would conserve resources and improve crop performance; “Globally, we find that closing yield gaps to 100% of attainable yields could increase worldwide crop production by 45% to 70% for most major crops (with 64%, 71% and 47% increases for maize, wheat and rice, respectively).” (Mueller, Gerber, Johnston, Ray, Ramankutty, and Foley 2012). Meeting future food demands is a dynamic problem that requires consideration of all things, but most importantly water and soil conservation.

Sustainable agriculture relies solely on natural processes for input and recycles nutrients on-site to eliminate the use of non-renewable resources. Alternatively, conventional agriculture requires an incredible amount of energy to produce, prepare, and transport food. Energy efficiency is important to agriculture as it can reduce greenhouse gas emissions and lower costs of production; “Agricultural activities (not including forest conversion) account for approximately 5% of anthropogenic emissions of CO₂ and the 10–12% of total global anthropogenic emissions of GHGs (5.1 to 6.1 Gt CO₂ eq. yr⁻¹ in 2005), accounting for nearly all the anthropogenic methane and one to two thirds of all anthropogenic nitrous oxide emissions are due to agricultural activities.” (Gomiero, Pimentel, and Paoletti 2011). Agriculture is responsible for a significant percentage of greenhouse gas emissions, but can also mitigate this impact using sustainable methods. Better management of agricultural land is required to reduce the effects of crop production.

Sustainable agriculture has the ability to offset global greenhouse emissions at a greater rate than conventional agriculture because it is more permanent and does not require much input to produce food. Conventional systems are inefficient at capturing carbon because of soil composition, constant production, and how much energy is being used to maintain the crops. “We use so much machinery, pesticides, irrigation, processing, and transportation that for every calorie that comes to the table, 10 calories or energy have been expended.” (Sustainablelafayette.org). However, there are measures that can be taken to increase energy efficiency. “This carbon can be stored in soil by SOM and by aboveground biomass through processes such as adopting rotations with cover crops and green manures to increase SOM, agro-forestry, and conservation-tillage systems.” (Gomiero, Pimentel, and Paoletti 2011). Conventional agriculture operates at a net energy loss, but implementing sustainable practices can reduce costs and benefit the surrounding landscape.

Sustainable agriculture aims to enhance the composition of a landscape while producing sufficient yields. This method is so efficient compared to conventional agriculture because it requires no input of synthetic chemicals or fertilizers, which accounts for a large amount of the greenhouse gas emissions. However, energy efficiency also takes into account the ratio of input to output. In that sense, there is no substantial difference between the two types of agriculture; “the energy efficiency, calculated as the yield divided by the energy use (MJ ha⁻¹), was generally higher in the organic system than in the conventional system, but the yields were also lower. This meant that conventional crop production had the highest net energy production, whereas organic crop production had the highest energy efficiency.” (Gomiero, Pimentel, and Paoletti 2011). Even though conventional systems produce greater yields than sustainable systems, organic crop production is the most energy efficient method.

VI. Conclusion

Studies point toward sustainable agriculture as the best solution to managing the growing population. Although the benefits of sustainable agriculture are abundant, there are several constraints to adopting this method worldwide. Climate conditions vary with geography so where sustainable agriculture is the most efficient system in one part of the world, it may not be entirely feasible in another. “Some authors suggest the adoption of integrated farming, rather than upholding solely organic practices, which they find more harmful than conventional farming, for instance in the case of pest control technologies.” (Gomiero, Pimentel, and Paoletti 2011). Many factors determine the performance of agricultural methods and often the most effective type of agriculture requires a combination of techniques. In addition to local constraints, sustainable agriculture also requires much more labor to maintain crops.

The science of agriculture has allowed human populations to grow exponentially and dominate the world’s landscapes. Advancements in this science have enabled humans to manipulate entire ecosystems to cater to their survival. But as populations continue to grow, resources are becoming limited. Water, fuel, and soil are three important factors determining the survival of the world’s population and it is crucial that they are used as efficiently as possible. In a comparison of sustainable and conventional agriculture, organic farming methods are shown to perform much better for a number of indicators. Sustainable agriculture consumes less water and energy, enhances soil composition, and forgoes synthetic chemical input. Conventional agriculture cannot meet the needs of the current population without compromising the integrity of the environment. Sustainable agriculture has the potential to sequester carbon, feed the world, and enrich the environment. The social, economic, and environmental benefits of this system are reasons why sustainable agriculture is the most viable way to accommodate growing trends.

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