"Farmer-Friendly" Sustainability Assessment of California Organic and Conventional Strawberry Farms.

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Abstract Strawberries are one of the most valuable crops in California, a highest demand produce in both organic and conventional forms. However, conventionally farmed strawberries are often associated with environmental degradation, health risks and high input costs, whereas organically farmed strawberries can reduce some of these issues. High premiums and increasing demand are incentives for the conversion of conventional to organic strawberry farming. This study assessed the environmental sustainability of organic and conventional strawberry farming in California based on soil quality and plant health. This study also aimed to bridge the gap in knowledge of reliable "farmer-friendly" methods that are practical, and quick, in monitoring the functioning status of farm ecosystem processes. I studied four farms- two organic and two conventional, in Santa Cruz and Watsonville. I measured soil quality and plant health based on nine indicators and, in support, I also tested for pH, N, P, and K. Organic management overall had a higher sustainability score than conventional management; however, the scores did not differ by much and both scored high on sustainability. Both managements also showed proximate N, P, and K levels, although Organic management had pH levels more adequate for strawberries. This study is inconclusive given the subjective nature of "farmer-friendly" assessment, however practical, and stronger nutrient level tests are needed in support thereof.

Introduction

The problems in conventional agriculture seem traceable to Green Revolution techniques of enhancing nature's limits of food production (Shiva 1991). Although modern agriculture feeds most of the global population, it comes at the expense of the environment (Badgley *et al.* 2006). Sustaining high crop yields requires intensive fertilizer and pesticide applications, higher water use and genetically modified seed strains. The industrial inputs of conventional agriculture pollute groundwater, aquatic and terrestrial habitats, harm biota and are persistent in the environment (Tilman *et al.* 2002). Genetic simplification through monoculture farming makes food production vulnerable to diseases and environmental catastrophes (Matson *et al.* 1997). However, conventional food production technology received wide governmental support to further increase national production and economic revenue (Cleaver 1972).

The main characteristics of modern agricultural systems are crop specialization, intensive use of inputs, and the aim for high yields. The crop specialization involves the use of genetically modified varieties with desirable attributes such as drought and disease tolerance (Tilman *et al.* 2002). Another characteristic of conventional agriculture is the use of inputs such as fertilizers, pesticides, and herbicides. From 2002 to 2006, fertilizer and pesticide inputs showed a continued increase in usage in the California agricultural sector, from about $1,704,000 to about $2,400,000. Lastly, California's high economic contribution in the agricultural sector is largely due to its high yields. Lastly, high yields are another main characteristic of California conventional agriculture, making it an important agricultural state (USDA 2007)..

The problems with the specialization of agriculture are apparent in the environment. Large-scale monocultures and high inputs of agrochemicals methods diminish soil quality and plant health, reduce agricultural biodiversity (Matson et al. 1997), pollute water, and create pest resistance to chemicals The high use of chemicals is hazardous to the health of exposed farm workers, neighboring residents, and wildlife (Kegley *et al.* 1999, Badgley *et al.* 2007). The continuous output of nutrients via produce and lack of organic replenishment, complemented by the soil high chemical content reduces soil fertility (Foster and Magdoff 2000, Altieri 1995). Chemical addition to the soil depletes beneficial insects and microbes in the soils (Doran and Parkin 1994), breaking the nutrient cycling of organic matter in the soil which negatively affects plant health due to lack of nutrients and higher disease vulnerability and incidence (Altieri and Nicholls 2004). As a result, more pesticides and fertilizers are added to the farm to alleviate lower crop yields (Tilman *et al.* 2002). The usage of methyl bromide, a now banned volatile agrochemical used as a pesticide and herbicide in the past, was thinning the ozone layer (Sydorovych *et al.* 2006). Agrochemicals, such as fertilizers, insecticides, and pesticides contaminate bodies of water, creating dead zones (Beman *et al.* 2004) and harming aquatic ecosystems, animals and humans. Agrochemicals percolate into the water table, persist in the soil and are found in animal tissues (Golam and Thapa 2004; Altieri 1995). Insecticide use increased by a factor of 10 from 1945 to 1989, while pest incidence doubled. This follows a positive feedback cycle, where pests have now developed resistance to most pesticides on the market, exacerbating the pest problem as beneficial predators of these pests also die. In response, farmers then continue to increase amount of insecticide use to combat new outbreaks. Secondary pests then appear and become an additional problem on the farm as they are unchecked by beneficial insects (Badgley *et al.* 2007).While the list of environmental problems with conventional agriculture continues, organic farming offers a more environmentally friendly management (Rodriguez *et al.* 2008).

One of California's biggest agricultural and economic contributions to the United Sates is its strawberry industry. After World War II, California's strawberry production increased from about four percent to up to 80 percent in the early 1980's, making California the leader in production (Wells 1996, Bertelsen 1995). To sustain such high yields, however, pesticides were used to control pests and weeds and fertilizer to maintain harvest yield. From 1941 to 1995, California conventional strawberry production became the principal contributor to the increase of pesticide inputs from 161 to 212 million pounds (Altieri 1995). The area of conventional strawberry farms grew from 22,600 acres in 1997 to 35,800 acres in 2006 (Klonsky and Richter 2007). The cost of production by 1996 was more than $61,500 per hectare, mainly due to intensive use of pesticides and herbicides (Gliessman *et al.* 1996).

Associated problems with massive strawberry production are greater densities of pests, occurrence of plant diseases, and increase in use of more pesticides. Pest players include spider mites, cutworms, armyworms, lygus bugs, aphids, cyclamen mite, thrips, and whiteflies. Common diseases affecting production are angular leaf spot, anthracnose, leaf blotch, powdery mildew, crown and root rot. To alleviate these problems, the Environmental Protection Agency advises conventional farms to fumigate with pesticides, fungicides, herbicides and also slow-releasing fertilizers for soil nutrient preparation (IPM 2008).

The importance of conversion from conventional to organic agriculture is associated with the amelioration of the environmental problems of conventional farming, such as soil erosion, pest resistance and reduction of biodiversity (Badgley *et al.* 2007). Organic farming supports soil quality as it nurtures soil fertility and biodiversity through methods of crop rotation, intercropping, polyculture, cover crops, manure, organic fertilizer, non-genetically modified organisms (GMOs), and biological pest control use (Reganold *et al.* 1987). These techniques and the employment of biodiversity are key in pest and weed management (Gomiero *et al.* 2008). Organic farming reduces the environmental pollution that conventional methods otherwise create in the process of production (Altieri 1995).

Organic farming is defined by the characteristics of (1) minimal externally derived inputs, and (2) restoration and support of biodiversity, soil fertility and quality, natural biological cycles and soil biological activity as synthetic inputs and seeds are prohibited (USDA 1980). The costs of conventional agriculture are high compared to organic farming, posing as an incentive for conversion. Conventional strawberry production suffers by pesticide-resistance spider mites that can be better controlled organically and through beneficial insects. The dependence of conventional management on high inputs and overall production costs make it less desirable *et al.* 2008. For example, nutrient addition to organic farms is known to be about 34 to 51 percent below the inputs of conventional agriculture (Mader et al. 2002), and total energy use decreases by nine to 51 percent upon absolute conversion to organic management (Hansen et al. 2001). Organic strawberry premiums are a major incentive for conversion to organic production, given that demand for organic produce is the largest contributor to organic market sales, with an annual growth rate of 21 percent in the 1997 to 2003 period (Lin et al. 2008). Sales in 2005 were 2.5 times those of 2000. The acreage of organic strawberry farming has increased from 509 acres in 2000 to 1,406 acres in 2005 (Klonsky and Richter 2007)

Monitoring the advance of transition from conventional to organic farming is important in order to improve management. However, there is a gap in knowledge of practical and quick methods for this assessment, as some proposed methods are not farmer-friendly (Masera *et al.* 2005) and previous studies on the comparison between organic and conventional strawberry farming involves time-consuming, complex methods (Gliessman *et al.* 1996a, 1996b).

Strawberries are worth about $300 million a year, a valuable crop for California and the nation. Given the high demand, strawberry production exerts high environmental pressures since conventional practices rely heavily on chemical spraying and hand labor (Gliessman *et al.* 1996). In my study, I will use a methodology for sustainability assessment that requires basic knowledge about the crop health and soil quality, and participatory help, all without the aid of costly technology. Assessment of the soil quality and plant health is based on physical characteristics specific to strawberries. The "farmer-friendly methodology" is inexpensive, practical as it reveals important information to see how well the processes within the farm ecosystem are functioning (Altieri and Nicholls 2005).

I studied two organic strawberry farms and two conventional strawberry farms in the Santa Cruz region of California. The general aim of my study is to assess the sustainability trends of organic and conventional strawberry farming in California using simple methodology for soil quality and plant health rankings. Specifically, I have the following three objectives: (1) assess the sustainability of each farm as separate case studies, (2) determine the similarities between farms of each farm management type, (3) compare the overall sustainability trends between organic management and the conventional management, and (4) determine whether the "farmer-friendly" method is a practical and valuable assessment. In my study, the definition of sustainability I will use is as follows: "A diversified system with biologically active and organic-rich soil, which subsidizes soil fertility, plant protection and productivity" (Altieri and Nichols 2005). In other words, sustainability relates to soil quality and plant health because good soil quality improves plant health, which ultimately benefits the farmer and the environment (Altieri and Nichols 2005).

I have two hypotheses. My first hypothesis is that there is no difference between these two system managements. My alternative hypothesis is that there is a difference between the two, namely that the organic farm has higher sustainability scores than the conventional farm. My second hypothesis is that soil tests for the two sampled organic farms exhibit adequate levels of pH, nitrogen, potassium and phosphorus that are in closer proximity to standard levels suggested for strawberry farms, while the two conventional farms do not.

Methods

To assess sustainability trends in California strawberry production, I conducted one observational study at four sites, two organic and two conventional farms. The two organic farms are UC Santa Cruz Center for Agroecology & Sustainable Food Systems (CASFS) in Santa Cruz (0.14 acres) and a farm from Berry Co-op in Watsonville, owned by Dean. The two conventional farms are part of Berry Co-op, one also owned by Dean and the other by Bryan.

The indicators of my methods cover important physical, chemical and biological properties of soil quality (Karlen et al. 1997). I measured soil quality and plant health because these two show that the agroecosystem is functioning adequately and sustainably. If the crop suffers poor health, perhaps that indicates that the soil quality is also poor (Thies and Grossman 2006; Doran and Parkin, 1994). Moreover, the indicators I used for determination soil quality and plant health cover the characteristics that make a farming management sustainable (citation).

The four farms vary significantly in location, size, detailed management practices, strawberry varieties, soil type etc (Table 1). I will not be making conclusive generalizations about strawberry farming itself, since these farms were not subjected to strict. Hence, each farm serves as a case study for which I can note general environmental sustainability trends for organic and for conventional farming separately based on relativity to the farms studied.

Table 1 Summary of differences between farms. Organic matter is abbreviated to OM.

	Farms	Year	Size (acres)	Soil	Practices
Organic	CASFS	1st	0.14	OM residue	pH: oyster shell lime, applied 20 years ago
					Fertilizer: sudan grass/vetch before sowing
	Dean	1st	25	Rocky	Fertilizer: Agrothrive, 2.5-1.5-1
					pH: not specified
Conventional	Bryan	1st	24	Sand	Fertilizer: foiler application
					Pest: bug vacuum surrounding alfalfa, spray
	Dean	1st	62	Clay	pH: acids as needed
					N: 5lbs a week
					PK: as needed with tissue samples

Data collection and rationale

I used a capful of water peroxide to rank effervescence in every handful of soil (one bottle contains enough for 40 capfuls), which will indicate microbiological activity (Altieri and

Nicholls 2005). I used a wire hanger, 11 inches long to test for soil compaction. I also used sandwich sized zip-lock baggies for soil collection and a soil NPK and pH test kit (EAC25448M, Nasco, Modesto, CA, USA).

I randomly selected 10 strawberry crops in each farm. I studied each of the nine indicators of soil quality and plant health per crop (Table 2 and Table 3). I assigned the sample a value 1, 5, or 10 according to established characteristics that correspond to each value that are specific to each indicator. A value of one signifies low sustainability, a five is the sustainability threshold and a 10 is the best quality ranking (Altieri and Nicholls 2005). I referenced USDA's "Soil Quality Test Kit Guide" (1999) and *Strawberry Deficiency Symptoms: A Visual and Plant Analysis Guide to Fertilization* (Ulrich and Allen 1980) for visual examples of some of the characteristics. To identify pest insects I used Intergrated Pest Management's (IPM) "UC Pest Management Guidelines" focusing on the following three major insects: spider mites, western flower thrips, and aphids. I calculated the mean value for soil quality and plant health per farm and for each farming management. I visualized the indicators in an amoeba-type graph (Altieri and Nicholls 2005) for each management so that I can visually find the similarities and the contrasts. I also visualized the overall sustainability trends of each management together by plotting each mean indicator value against each farm (Altieri and Nicholls 2005).

Table 2 Soil quality indicators for strawberry farms, with designated values for all characteristics.

Indicators of soil quality	Established value	Characteristics
Structure	1	Loose, powdery soil without visible aggregates
	5	Few aggregates
	10	Well-formed aggregates
Compaction	1	Compacted soil, cannot penetrate with pen
	5	Thin compacted layer
	10	No compaction, penetration all the way into soil
Status of residues	1	Slowly decomposing organic residues
	5	Presence of last year's residues
	10	Residues at various stages of decomposition
Color, odor, and organic matter	1	Pale, chemical odor, no presence of humus
	5	Light brown, odorless, some presence of humus
	10	Dark brown, fresh odor and abundant humus

Water retention (moisture level after irrigation of rain)	1 5 10	Dry soil Limited moisture level for short time Reasonable moisture level for reasonable time
Soil cover	1 5 10	Bare soil >50% soil cover by residues or live cover <50% soil cover by residues or live cover
Erosion	1 5 10	Severe erosion, presence of small gullies Evident, but low erosion signs No visible signs of erosion
Presence of invertebrates	1 5 10	No signs of invertebrate presence or activity A few earthworms and arthropod present Abundant presence of invertebrate organisms
Microbiological activity	1 5 10	water peroxide: very little effervescence light to medium effervescence abundant effervescence

Table 3 Plant health indicators for strawberry farms, with designated values for all characteristics.

Indicators of plant health	Established value	Characteristics
Appearance	1 5 10	Chlorotic, discolored foliage with deficiency signs Light green foliage with some discoloring Dark green foliage, no deficiency signs
Crop growth	1 5 10	Short and thin branches, limited new growth Thicker branches, some new growth Vigorous growth
Disease incidence	1 5 10	Susceptible, <50% of plants with damaged leaves and/or fruits Between 25%-45% plants with damage Resistant, with >20% of plants with light damage
Insect pest incidence	1 5 10	<15 insects per leaf, or more than 85% damaged leaves Between 5-14 insects per leaf, or 30-40% damaged leaves >5 insects per lead, >30% damaged leaves
Natural enemy abundance and diversity	1 5 10	No presence of predators/parasites detected At least one individual of one or more beneficial species At least two individuals of one or two beneficial species
Weed competition and pressure	1 5	Crops stressed, overwhelmed by weeds Medium presence of weeds, some level of competition

	10	Vigorous crop, overcomes weeds
Fruit quality	1 5 10	Low in relation to local average Medium, acceptable Good or high
Vegetational diversity	1 5 10	Monoculture A few weeds present of uneven cover crop With dense cover crop or weedy background
Natural surrounding vegetation	1 5 10	Surrounded by other crops, no natural vegetation Adjacent to natural vegetation on at least one side of crop Surrounded by natural vegetation on at least two sides

I analyzed soil nitrogen, phosphorus, and potassium, which are major soil nutrients, and pH (Ulrich and Allen 1980). The soil tests were used in an attempt quantitatively validate the use of the "farmer-friendly" method of soil indicators, since the latter uses visual scores. I dried the collected soil, filtered it using the solutions in the test kit, and added the appropriate reactant. Then I compared the solute to the kit's card index to obtain a low, med, or high score, each with a range of respective values for concentration.

Results

The two sampled organic strawberry farms have higher total average sustainability scores for soil quality and plant health indicators than the three sampled conventional farms (Table 4). CASFS (organic) averages the highest in both soil quality and plant health, with a total average of 9.96. Dean's organic farm, however, falls closely in scores to the two other conventional farms. Bryan's farm had the lowest score of them all, 5.95 for soil quality, and its plant health score (7.45) was higher than Dean's organic farm's plant health score. I visually analyzed my data (Fig. 1) to compare the sustainability of the farms relative to one another. All four farms scored above a five, which is the sustainability threshold.

Table 4 Results of "Farmer-friendly" assessment for each farm.

	Farm	Soil Quality	Plant Health	Total avg.
Organic	CASFS	9.353	9.96	9.66
	Dean	7.85	7.23	7.54
Conventional	Bryan	5.95	7.45	6.7

	Dean	7.39	6.69	7.04

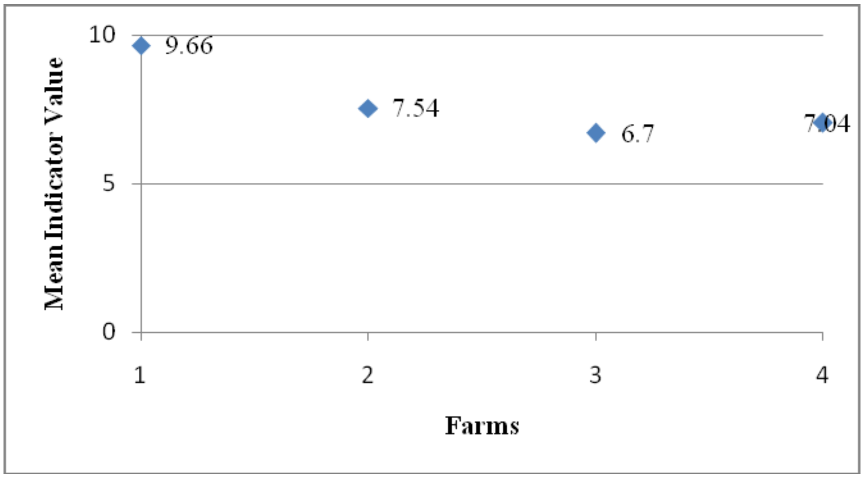

Figure 1 Comparison of combined averages of soil and plant indicators of farms. A five is the sustainability threshold level.

For my second hypothesis, results for all four farms for N, P, and K were very similar (table 5). In terms of adequate levels of low, medium, and high, they were exactly the same. Both managements also showed the same overall scores as well, differing not by much. In terms of of adequacy levels, they both also share the same levels. However, organic management overall scores were slightly lower than those for the conventional scores. The pH levels for organic farms and for the overall management score were lower than those for conventional farms (Table 6).

Table 5 Soil test score of all four farms for N, P, K and pH.

	Farms	N (mg/l)	P (mg/l)	K (mg/l)	pH
Organic	CASFS	13	50	120-160	6.05
	Dean	7	50	170-205	6.55
Conventional	Bryan	10	50	40-85	7
	Dean	15	60	300-325	7.45

Table 6 Soil test results of N, P, K, and pH by management.

Management	N (mg/l)	P (mg/l)	K (mg/l)	pH

Organic	10	50	145-182.5	6.3
Conventional	12.5	55	170-205	7.225

Discussion

The data from the two sampled organic farms follow trends of sustainability, in that they show better soil quality and plant health averages. The data from the two sampled conventional farms showed lower sustainability scores, in that both soil quality and plant health averages were lower than the sampled organic farms. This raises the question of whether there is an actual difference between management or if there is bias towards expected scores between organic and conventional farming. Can sustainability be achieved in conventional management given that the scores did not vary largely?

Additionally, the soil tests for both managements showed levels of pH, nitrogen, potassium and phosphorus that are in closer proximity to one another. The use of composted plant residue for soil nutrient feed helps improve soil quality as opposed to intensive (conventional) management where crop residues are not left fallow (Karlen et al. 1997). However, we saw in this study that the managements did not vary greatly. The tolerant pH for strawberry ranges from 5.5 to 6.5 (slightly acidic) and the organic farms fell under these levels whereas the conventional farms had more neutral levels.

Though strawberries have different nutrient cycling and supply requirements than other crops in different environments (Karlen et al. 1997), I was surprised to find strawberry farms with extremely different soil types (clay-based and sand-based, blocky structures and high in hummus). Different soil types along with pH, influence nutrient availability, CEC of the soil and water retention. However, in my study, the soil type differences did not seem to influence the results.

This quick, "farmer-friendly" method may work for an individual farmer if characteristics for indicators are sensitive to significant changes in quality of soil and plant. However, in terms of the soil tests, I cannot conclude because the tests were not precise since they were not conducted in a laboratory. On the other hand, sustainability scores did not vary largely between managements as well as for the soil tests. This could mean that the method does work. I took qualitative characteristics and quantifying them. There is no direct conversion between the two excepting the relativity between farms. The "farmer friendly" methodology is highly subjective and each farmer holds different perspectives on what good characteristics are. Hence, my data is not necessarily factual or replicable, for my averages may significantly differ depending on who samples the very same farms that I studied.

Overall, these results seem to reflect their respective sustainability scores of soil quality and plant health. The efficacy of the "farmer-friendly" approach for sustainability assessment could perhaps be demonstrated if more precise and rigorous research is conducted.

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