CHANGE DYNAMICS IN MAHARASHTRA STATE SMALL FARMING SYSTEMS - FIELD SURVEY AND ANALYSIS THROUGH ANALYTICAL HIERARCHY PROCESS

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ABSTRACT

Several issues threaten the sustainability of small farms. During the 1970-80's, the Green revolution helped the Indian food supplies become more self-sufficient; however, the post Green Revolution situation is not certain. Farmers prefer and accept farming practices that provide good economic returns as well as proper care for the environment. The scientific community, policy makers and farmers themselves are confronted with difficult decisions in selecting the optimal agricultural practices. This paper reports results from a study that uses a multi-criteria analysis tool called AHP (Analytical Hierarchical Process) to assess options such as chemical, organic and partial organic farming. Farmers practicing these three different farming systems were interviewed and asked to fill out a questionnaire, and both quantitative and qualitative attributes was synthesized. Three different crops (i.e. rice, sugarcane and mango) were considered for AHP analysis. The AHP methodology is useful in explaining multi-criteria analysis to the extension agents and opinion makers, and may help convince these people to support the use of best farming practices while keeping sustainability in mind (Kiyotada H., 2000).

Keywords: Farming Systems, multi-criteria Analysis, AHP Ranking

1. Introduction

India has 329 million hectares of agricultural land, which amounts to 0.28 ha/Ca (hectare per capita) as compared to the world's average of 0.76 ha/Ca. In order to maintain the current food consumption levels per capita, assuming current rates of population growth and no further agricultural intensification, agriculture would need an area equivalent to one half of the current terrestrial land area by 2030 and two-third by 2070 (Chaudhary et al., 2005). At present, India's agricultural growth rate is exceeding the population growth rate. However, Indian farming systems also need to address the 'sustainability' question. Indian farmers are facing serious problems such

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as declining ground water levels, electricity shortages, marketing risk, and climate variability. Traditional culture and social values are changing as the attraction of migrating to cities is increasing. Following a monotonic crop pattern for many years, farmers sell the surplus of their production after fulfilling their own requirements. Most of the farmers have small areas of land, and the income from these small farms is not enough to sustain their livelihood. Therefore, these farmers are dependent on other livelihood options like small jobs in towns or nearby larger farms. The younger generation is not interested in farm related work due to the availability of less laborious job opportunities in towns and cities that seemingly provide higher cash returns. During the course of our surveys, we observed that 30-40 % of the available farmland has been kept fallow for a stretch of several years. One of the reasons for this is that even though the yield of the crop has not drastically reduced (physical/energy ratios more than 1 as explained in section 2.1), the economic efficiency of agriculture is much lower than other occupations in the studied areas. Future cropping systems and farm management options need to address these issues in order to reduce sustainability risks. Such farm practices would potentially drive cost reduction in agriculture inputs, advanced holistic farm training, transport cost reduction of farm produce, knowledge about local market, value addition, etc. With all this in mind, it is important that farmers are provided inputs for decision making based on environmental, social, technical and economic perspectives. In this article, the Analytical Hierarchy Process (AHP) is used for policy planning at the village level, and its application in choosing the best farming practices between organic, chemical and partial organic farming, is explained from each of the four perspectives mentioned above.

1.1 Chemical, organic and partial organic farming systems

In India, a variety of farming practices have been prevalent since ancient times. This can be partially attributed to the fact that India has different climatic zones. This is an advantage as multiple crops can be grown and different cultivation patterns can be adopted in different regions. However, regardless of the zones and crop patterns, three different farming practices exist in India in general, namely, organic farming, partial organic farming and chemical farming. **Organic farming** is characterized by the absence of external chemical inputs. **Partial organic farming practices** involve minimal external chemical input along with organic input from the farm itself, while **chemical farming** relies completely on specified external chemical input. Even within organic farming, a variety of farming practices exist in India. There are several organic fertilizers and pesticides, each having its own effect on crops and human health.

Many of the organic farming practices are diminishing because of industrialized farming and market driven external inputs. The usage aspect of fertilizer that originated with the Green Revolution has been overdone, leading to soil degradation and subsequent reduction in yield, irrespective of increase in the external inputs of fertilizers, seeds and pesticides. Organic farming is based on the foundational principle of maintaining soil nutrition. However, introduction of organic practices does not seem to be increasing the yield in the proportion desired to satisfy the ever growing needs. Reddy (2010) provides an accepted definition of organic farming as: “Organic agriculture is holistic production management systems which promote and enhance agro-ecosystem health, including biodiversity, biological cycles and soil biological activity”. Reddy also cites a number of studies which gives yield/productivities at higher as well as lower levels. Recently, the idea of an evergreen revolution, promoted by several agriculture planning bodies in India, stresses that the crop productivities can be enhanced by increasing the soil nutrition

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and by using a high yielding variety of seeds, as well as biotic and abiotic stress resistance variety of seeds. The evergreen revolution has its roots in biotechnology. While the profit and market oriented Green Revolution served its purpose in the initial years, the indiscriminate use of fertilizers and pesticides has led to undesirable consequences two and half decades later, especially in states such as Punjab and Haryana. The yield and underground water levels have decreased drastically. Water pollution, soil salinity, pesticide residue, indebtedness and suicides are common problems faced by the present day Indian farmer. There is an increasing awareness amongst farmers about the economic effects of the Green Revolution on soil and yield. Partial organic farming practices are increasingly turning out to be a socially, technically, environmentally as well as economically viable farming practice in several parts of India. Several NGOs have been motivating farmers to mix organic biomass and fertilizers with the soil. Research has shown that application of a small percent of chemical fertilizer and organic biomass/fertilizers gives more yield than the exclusive use of organic or chemical farming practices associated with environmental benefits (Schneider et al., 2011). The agriculture marketing system is one of the most complex issues due to governance and control by both local and central government bodies. After selling agriculture produce to a commission agent at an APMC (Agricultural Produce Market Committee) market, farmers only get a 30% return by the time the produce reaches the consumer. This results in the consumer getting costly food and the farmers getting limited rewards.

2. Agriculture-food-health connection (consumer concerns)

Food obtained by organic farming has been found to be richer in nutrients like vitamin C, iron, magnesium, and phosphorus and contain significantly fewer nitrates as compared to chemically grown food (Worthington et al., 2001). During the course of experiments performed in our field surveys, we found that 1 kg of chemically grown sugarcane contains a sweetness equivalent to 0.65 Kg of its organic counterpart. Additionally, the final dry mass of chemical sugarcane is 10% less than those grown organically. Similar results have been observed with other vegetables (Woese et al., 1997). Chemically grown vegetables contain a lower percentage of antioxidants in comparison to organic produce (Ren et al., 2001; Carbonaro et al., 2002). In summary, chemically grown food, while apparently solving the problem of quantity of production, potentially compromises on quality, measured in terms of nutrient content. Moreover, pesticide residues can cause long-term chronic diseases like cancer (Dich et al., 1997; Zahm & Blair, 1992), liver and kidney damage (Amr, 1999), disorders of the nervous system (Dich et al., 1997), birth defects (Garry, Schreinemachers & Harkins, 1996), and disruption of the immune system (Zahm & Blair, 1992). Pesticides can cause irreparable health disorders as they accumulate in the body fat. A report (Mathur, 2005) found nearly six to thirteen pesticides in virtually all blood samples, some of them were: HCH, Aldrin, DDT, Monocrotophos, Endosulfan, Phosphamidon, Chlorpyrifos and Malathion. Past studies in Punjab have revealed pesticide residues in breast milk (Kalra, Singh & Battu, 1994), milk from cattle (Kalra et al., 1999), and fruits and vegetables. Pesticide use in India has increased by two orders of magnitude - from 154 million tons in 1954 to 88,000 million tons in 200l. Punjab is one of the largest consumers of pesticides at 6,972 million tons a year (Menon Ramesh, 2005). Figure 1 (Rao, C. H. S. et al., 2005) shows the increasing number of cases of acute pesticide poisoning in a hospital in Andhra Pradesh (AP), and this is representative of other parts of India. Chronic diseases account for the largest number of deaths in India with communicable diseases, maternal and prenatal conditions, and nutritional deficiencies following behind (World Health Organization). These signs indicate that while India's food security may be addressed in coming years, food safety concerns still need to be

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addressed. We found in our survey that 85% of the farmers growing vegetables and fruits with the aid of pesticides and fertilizers do not eat the vegetables and fruits from their own farms. However, they do consciously isolate some areas in their farm that are kept free from chemical pesticides and fertilizers, and personally use produce only from such areas.

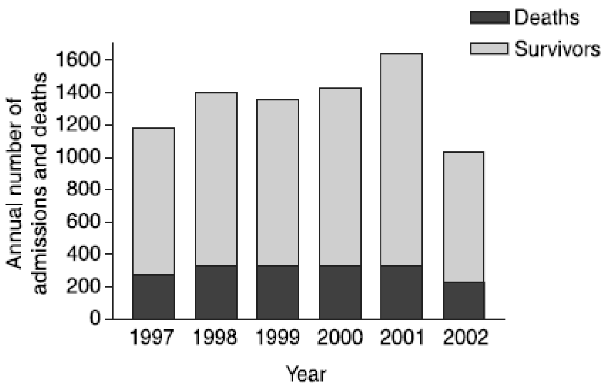

Figure 1. Yearly admission and deaths related to pesticide toxicity at the Mahatma Gandhi Memorial Hospital Warangal (AP) during (1997-20002)

2.1 Physical /energy conversion ratios and financial efficiencies

Energy conversion ratio in paddy cultivation was computed by considering energy equivalents of seed, fertilizer (organic and inorganic) human and animal labour, tractor and the paddy crop as output (Ramchndra, & Nagarathna, 2001). Energy efficiency of a rice crop in the surveyed areas was found to be 3.16. Costs of various farming operations for the rice crop in the Nane and Vadap villages in the Konkan area of Maharshtra (India), and the revenue generated in monetary units were used in computing economic efficiencies. It was found that the economic efficiency for the paddy crop is 0.3. These two efficiency numbers indicate that while the energy efficiencies are adequate the economic efficiencies need improvement.

3. Call for technological changes

During our survey, it became apparent that the undesired effects of the Green Revolution are well understood by Indian farmers. This realization over the past few years has prompted the use of compost and biomass in many parts of India. However, this method needs larger acceptance and practice. In this paper, we used a multi-criteria decision making technique called the Analytical Hierarchy Process (AHP) to analyze and rank the alternative technologies for farming, in order to enhance the practice of doing alternate farming practice amongst a wider mass that includes the development workers. While we have used AHP for ranking three high level alternative farming practices based on a combination of qualitative and quantitative attributes, the same procedure can be used to select amongst more specific alternatives, such as the choice of certain crops in certain seasons, the cropping patterns, the choice of seed quality, the type of tillage to be employed, the appropriate methods for water conservation, the alternatives for water pumping, the selection of markets and so on. The AHP process was applied from each of 4 different perspectives, namely, economic, environmental, technological and social.

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4. Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured technique for multi-criteria decision making. Ranking of solution alternatives is based on mathematics and human psychology. Rather than prescribing a "correct" decision, the AHP helps people to prioritize from available alternatives. Inputs to the AHP are:

- A set of technology alternatives
- A set of qualitative and quantitative attributes which potentially influence the preference of one technology over the other (these could be optimally arranged in hierarchy)
- Values of the quantitative attributes for each alternative could be cost/benefit depending on the perspective of the decision maker.
- Pair-wise preference values of the technology alternatives with respect to each qualitative attribute.
- Pair wise preference values of each attribute with respect to every other attribute.

The output of the AHP procedure is a consolidated score for each technology alternative based on how the alternatives are ranked. Internally, AHP uses Eigen decomposition analysis of the pair wise comparison matrices to compute relative weights of the attributes and weights of the alternatives with respect to qualitative attributes. The strength of the AHP that is leveraged in this work is its ability to analyze such qualitative/subjective inputs by converting them into quantitative/objective values. Additionally, the AHP provides indicators reflecting the consistency of the qualitative inputs. For example, if A is twice as preferred as B, and B is twice as preferred as C, then A being only half as preferred as C could lead to inconsistency that needs to be dealt with. Our analysis in the work presented here is heavily driven by qualitative as well as quantitative inputs from farmers which makes the AHP a suitable ranking tool. Rezaei-Moghaddam & Karami (2007) present the use of AHP for the selection of a sustainable agriculture development model between the two alternatives of ecological modernization and de-modernization. They employ nine criteria in the selection process. Four different groups, namely, Elite farmers, Lapuei's Women Committee, Lapuei's Sustainable Development Cooperative, and the Green Development Society were interviewed with questions based on these nine different criteria. Alphonce (1997) presented possible uses of AHP for decision making in agriculture. The following problems were explored:

- farm portions to allocate to each of the food crops,
- resource allocation to agricultural activities,
- best location for a village store,
- choice between subsistence and cash crops production, and
- determination of the crop production technology

Mawapanga and Debertin (1996) explain the use of AHP in multi-criteria decision making in agriculture using a participatory approach. Three alternative farming practices *i.e.*, conventional farming, biodynamic farming and organic farming are analyzed using four perspectives, namely, sustainability, profit maximization, health concerns and environmental concerns. Karami (2006) presents analysis of alternative water irrigation systems with three groups of farmers using nine objective criteria. In Parra-Lopez, Calatrava-Requena and De-Haro-Gimenez (2008) they use AHP for choosing a best alternative amongst different farming systems (that is, organic, conventional and integrated) for the production of olives. The author studied four

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perspectives which were social, technological, environmental and economic. Mahajan, Ramkrishnan & Date (2008) present web based Java software for AHP.

5. Objectives

The objectives of our research are as follows:

a. To capture the changes in agricultural practice in specific regions in western India through a sample survey of farmers for three crops: rice, mango and sugarcane.
b. To examine the process of decision making by using a multi-criteria analysis tool called Analytical Hierarchy Process (AHP).

6. Research methodology

The attributes to be used in the AHP model were chosen based on discussions with agriculture specialists, farmers, agriculture university experts and relevant literature. The attributes chosen focused on those things which were in line with the interests of the farmers. Farmers farm in order to have sufficient food for their families, and then they sell the surplus to increase their income. However, when the objective of farming is monetary reward, the farmer employs all necessary means keeping in mind yield enhancement. After facing the side effects of chemical farming, some farmers have realized the importance of sustainable agricultural practices and are beginning to be interested in environmental, social and technological perspectives. Three different crop systems i.e. rice, sugarcane and, mango were studied. Figure 2 depicts a schematic representation of the different perspectives and attributes (both qualitative and quantitative) considered while making decisions on choice of the farming practice. Following Saaty (1994), we used numerical ratings (in the range of 1-9) for qualitative attributes, as prescribed in Table 1. In this study, the regions that were selected for the application of AHP over three different crop systems are from Thane, Kolhapur, Solapur, and Jalgaon districts in Maharashtra (western state in India). The choice of criteria, perspectives, and alternatives were decided upon after consulting the farmers and agricultural experts. Farmers were selected based on the field survey and those who showed interest in our study. Detailed questionnaires were designed and revised based on experiences from the field survey. Three different farming practices, namely, organic farming, chemical farming and partial organic farming were selected as technological alternatives. These alternatives are selected based on 32 sub criteria under four perspectives (*i.e.*, economic, environmental, social and technological). The four perspectives are described in the next section.

In this survey, we collected data from 63 farmers (17 organic, 23 chemical and 23 partial organic) who agreed to respond to our questionnaires. Thus, our sampling method is not random, but it is *purposive sampling*. The socio-economic and educational backgrounds of the farmers who were surveyed are provided in Tables 3, 5, and 6 for sugarcane, mango and rice respectively.

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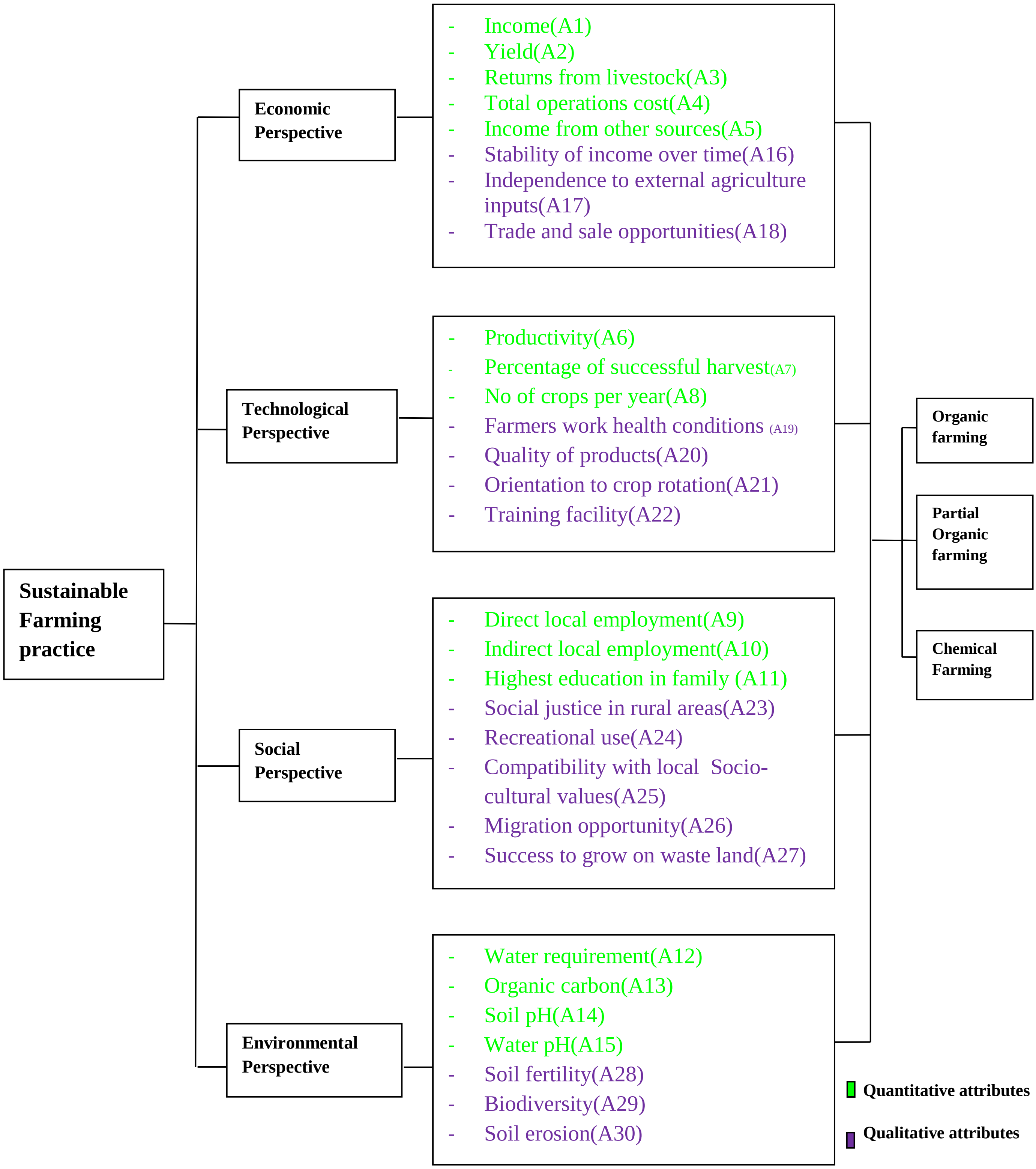

Figure 2. AHP Model for choosing sustainable agriculture practice for sugarcane, rice and mango

Table 1
Judgment scores for the importance/preference of criteria using AHP (Saaty, 1994)

Verbal Judgment	**Numerical rating**
Extremely important / preferred	9
Very strongly to extremely important / preferred	8
Very strongly important / preferred	7
Strongly to very strongly important / preferred	6
Strongly important / preferred	5
Moderately to strongly important / preferred	4
Moderately important / preferred	3
Equally to moderately important / preferred	2
Equally important / preferred	1

6.1 Economic perspective

- Farm income is calculated based on the total sales and expenses throughout the year. It includes the interest on capital, external farm inputs, salaries to workers, and other expenses. These items are restricted only for the crop under study.
- Income from other sources includes income from animals, selling vermin-compost, income from intercrop. Income other than farming activity is not considered.
- Total operations cost is the cost of land preparation, fertilizer, salaries of workers, pesticides, water, fuel etc.
- Value of major livestock owned is the value of animals which farmers own on their farm.
- Yield is the output from the crops after harvesting (Kg/acre)
- Stability of income over time is the measure, which illustrates whether income coming from the farm is long periodic or short periodic. It is from the intercrops like vegetables, flowers etc. that give regular income.
- Independence from external agriculture inputs like chemical fertilizers, seed, pesticides, farm mechanization machinery etc.
- Trade and sale opportunities are the opportunities available for selling the agriculture products. Discussions with farmers indicate that they feel more comfortable if their products get sold on their doorstep.

6.2 Technological perspective

- Productivity is measured as the ratio of agricultural outputs to agricultural inputs. Percentage of successful harvest depends on the risk associated with a contingent loss of production usually related to biological and agronomic conditions of the cultivation.
- Number of crops per year is the total number of crops on the same farm throughout the year.
- Farmers work health conditions relates to health problems due to chemical pesticide, water pollution, and new pest varieties etc.

- Quality of products is ascertained from criteria like nutritional value, taste, smell, shape, size etc.
- Orientation to crop rotation is the pattern of crops on the same farm.
- Training facility is the availability of getting training from different sources like NGOs, government training centers, agriculture specialists etc.

6.3 Social perspective

- Direct local employment is the opportunity that is made available due to the particular farming system on the farm and outside the farm.
- Indirect local employment is the employment created indirectly like the rural tourism, organic centers, local farm input industries etc.
- The level of education in the family is an important parameter to compare the different farming practices, and its relevance with the cultural aspects.
- Social justice in a rural area is about integrity in the community because of a changed style of farming.
- Recreational use is related to the concept of tourism for attracting the city population to get the feel of the rural environment. It is also important in terms of spreading traditional knowledge and history.
- Wasteland includes regions which do not produce the regular crop due to the bad soil health. There are holistic methods to grow crops in such areas.
- Compatibility with local socio-cultural values includes whether a farmer faces difficulties from other farmers after changing their farming practice.
- Migration opportunity is the opportunity the farmers in a given region consider when deciding whether to go to city to obtain a higher income.

6.4 Environmental perspective

- Water requirement is the periodic frequency of watering the crops.
- Water ph recommended for irrigation water is from 6.5 to 8.4. This technological information is verified by the NGOs and the public health centre.
- Soil ph recommended for different crop is from 5.5.to 8.
- Organic carbon is a major criteria considered by farmers to evaluate soil fertility.
- Soil fertility was related to the agronomic quality of soil, which depends on soil structure and low levels of pollution/contamination.
- Biodiversity which can be measured as the number and variety of different living beings present, including diversity of the sugarcane and rice and mango crop, wildlife, micro fauna, beneficial fauna, domestic animals and wild flora.
- Soil erosion is measured based on the slope of field and maximum rainfall.

Table 2 provides details about the farmers who were surveyed giving average farm size, number of farmers surveyed, irrigation method, marketing method and type of seeds used. It is observed that a large number of organic farmers are using local variety seeds and use direct to customer marketing method. Tables 3, 5, 6 contain the data obtained from the various surveys. This quantitative data is for three different crops with three different farm practices. Table 4 gives data about the nature of the attributes. The nature of the attribute is judged as a cost or a benefit. An attribute is considered a cost if it increases with time causing a negative effect. It is considered a benefit if it has a positive effect. For example, if the water requirement for any crop increases over time, it increases the cost of pumping for the same crop. However, if it decreases over a period of time it is beneficial. In chemical sugarcane farming the water retaining capacity of soil decreases, and therefore more water is required. In the case of organic sugarcane farming, the water requirement decreases as soil organic carbon content increases.

Table 2
Details from the farmers' fields

Crop	**Type of farming**	**No. of farmers interviewed**	**Average farm size (Acre)**	**Irrigation method**	**Marketing method**	**Seed (hybrid/ local)**
Rice	Organic Farming	7	3.5	(4 well water + 1 rainfed)	4 direct customer + 3 middle man)	(2 Hybrid + 3Local)
	Chemical Farming	7	3	(5 well water + 2 rainfed)	4 direct customer + 3 middle man)	All Hybrid
	Partial Farming	7	2.5	(4 well water + 3 rainfed)	4 direct customer + 3 middle man)	All Hybrid
Sugarcane	Organic Farming	5	2	Well and canal	Direct to Sugar Factory	All Hybrid
	Chemical Farming	8	3	Well and canal	Direct to Sugar Factory	All Hybrid
	Partial Farming	8	3	Well and canal	Direct to Sugar Factory	All Hybrid
Mango	Organic Farming	5	1.5	(4 well water + 1 rainfed)	4 direct customer + 1 middle man)	Local
	Chemical Farming	8	1	(5 well water + 3 rainfed)	1 direct customer + 7 middle man)	Local
	Partial Farming	8	1.5	(6 well water + 2 rainfed)	2 direct customer + 6 middle man)	Local

Table 3
Quantitative data for the sugarcane crop

No.	**Quantitative Attributes**	**Organic Farming**	**Chemical Farming**	**Partial Organic Farming**
Economic Perspective				
A1	Income (Rs/Acre)	63765	55789	78947
A2	Yield (tons/Acre)	42	42	52
A3	Value of major livestock owned (Rs)	78000	5000	30000
A4	Total Operations cost (Rs/Acre)	19120	30040	42105
A5	Income from other source (Rs)	60000	30000	40000
Technological Perspective				
A6	Productivity	4.1	2.5	3.5
A7	Percentage of successful harvest (%)	90	60	70
A8	No of crops/year	6	2	3
Social Perspective				
A9	Direct local employment (%)	30	-10	24
A10	Indirect local employment (%)	30	-12	20
A11	Highest education in family	15	10	12
Environmental Perspective				
A12	Water requirement (inches/year)	20	46.8	34
A13	Water ph	7.5	8	7.5
A14	Soil ph	6.5	7.4	7
A15	Organic Carbon	1.5	0.6	0.8

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Table 4
Nature of quantitative attributes (cost/benefit) for all crops

	Criteria	**Cost/Benefit**
A1	Income	Benefit
A2	Yield	Benefit
A3	Value of major livestock owned	Cost
A4	Total Operations cost	Cost
A5	Income from other source	Benefit
A6	Productivity	Benefit
A7	Harvest growing success prospects	Benefit
A8	No of crops per year	Benefit
A9	Direct local employment	Benefit
A10	Indirect local employment	Benefit
A11	Highest education in family	Benefit
A12	Water requirement	Cost
A13	Water ph	Cost
A14	Soil ph	Cost
A15	Organic Carbon	Benefit

Table 5
Quantitative data for the Mango crop

No.	Quantitative Attributes	Organic Farming	Chemical Farming	Partial Organic Farming
Economic Perspective				
A1	Income (Rs/Acre)	190000	150000	170000
A2	Yield (Kg/Acre)	2500	2700	2600
A3	Value of major livestock owned (Rs)	150000	75000	100000
A4	Total Operations cost (Rs)	35000	30000	33000
A5	Income from other source (Rs)	80000	50000	60000
Technological Perspective				
A6	Productivity	9	7.8	8.1
A7	Percentage of successful harvest (%)	90	60	70
A8	No of crops per year	6	2	3
Social Perspective				
A9	Direct local employment (%)	30	-10	24
A10	Indirect local employment (%)	30	-12	20
A11	Highest education in family (Standard)	15	10	12
Environmental Perspective				
A12	Water requirement (inches / year)	--	--	--
A13	Water ph	7.5	7	7.3
A14	Soil ph	7.5	6.3	6.5
A15	Organic Carbon (%)	2.5	1.8	2

Table 6
Quantitative data for the Rice crop

No.	Quantitative Attributes	Organic Farming	Chemical Farming	Partial Organic Farming
Economic Perspective				
A1	Income (Rs/Acre)	9150	-4200	2750
A2	Yield (Kg per Acre)	560	600	750
A3	Value of major livestock owned (Rs)	88000	5000	50000
A4	Total Operations cost (Rs/Acre)	4860	10200	8500
A5	Income from other source (Rs)	50000	15000	30000
Technological Perspective				
A6	Productivity	10.8	5	4.3
A7	Harvest growing success prospects	90	60	70
A8	No of crops per year	6	2	3
Sociocultural Perspective				
A9	Direct local employment (%)	30	-10	24
A10	Indirect local employment (%)	30	-12	20
A11	Highest education in family	15	10	12
Environmental Perspective				
A12	Water requirement (inches / year)	19	31	23
A13	Water ph	7	7.5	7.5
A14	Soil ph	6.7	7.3	7
A15	Organic Carbon	1.5	0.8	1.2

7. Stepwise calculation of technology ranking in AHP

To understand how the final rankings were obtained, the stepwise calculation of AHP methodology will be explained. For each separate perspective the AHP is used throughout the hierarchy. For example, if the goal is to determine a sustainable farming practice for mango cultivation among organic, partial organic and chemical farming with an economic perspective, the attributes taken into consideration are as shown Figure 2. These are quantitative attributes (A1, A2, A3, A4, A5) and qualitative attributes (A16, A17, A18). Similarly, from the technological perspective, the attributes taken into consideration are A6, A7, A8, A19, A20, A11, A22. Likewise, for the social and environmental perspectives, attributes are shown in Figure 2. The same method is used for the rice and sugarcane crops when implementing the AHP method. As discussed in Section 6, this work considered three crops and four perspectives for evaluating the performance the AHP method. Therefore, is it implemented (3×4) 12 separate times to obtain the final rankings. A detailed procedure for AHP is discussed below for the sugarcane crop from the economic perspective. The same method was implemented for ranking all of the hierarchies for each crop in order to calculate the final ranking. Table 7 extracts the

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specific quantitative attributes computed for sugarcane. AHP is implemented using JAVA web based software developed by Mahajan, Ramkrishnan, and Date (2008).

Table 7
Quantitative attributes for sugarcane crop

No.	Quantitative Attributes	Organic Farming (T1)	Chemical Farming (T2)	Partial Organic Farming (T3)
Economic Perspective				
A1	Income (Rs/Acre)	63765	55789	78947
A2	Yield (tons/Acre)	42	42	52
A3	Value of major livestock owned (Rs)	78000	5000	30000
A4	Total Operations cost (Rs/Acre)	19120	30040	42105
A5	Income from other source (Rs)	60000	30000	40000

The above data was inputted into the software, and normalization of the attributes was done by using Equations 1 and 2 in this software.

For Benefit attribute $$P_{ij} = \frac{t_{ij} - t_i^{\min}}{t_i^{\max} - t_i^{\min}} \quad (1)$$

For Cost attribute $$P_{ij} = \frac{t_i^{\max} - t_{ij}}{t_i^{\max} - t_i^{\min}} \quad (2)$$

Where 't' is the actual value, 'p' is the normalized value, 'i' is the number of a row and 'j' is the number of a column. Therefore, the normalized matrix of the quantitative data in Table 7 is obtained from the software and shown in Table 8.

Table 8
Normalized quantitative matrix

Attribute	T1	T2	T3
A1	0.34	0	1
A2	0	0	1
A3	0	1	0.66
A4	1	0.52	0
A5	1	0	0.33

Next, priority vectors (weights) are calculated by pair wise comparison of attribute to attribute data as shown in Table 9. Here the Eigenvector was calculated and the summation of all the Eigenvectors (-0.2565, -0.1309, -0.1133, -0.2745, -0.1678, -

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0.8411, -0.1314, -0.2757) is -2.1912. The value of this summation is used to divide each Eigenvector to get the priority vector. The consistency of the pair wise comparison was checked by the consistency ratio (CR). The consistency ratio was calculated by Equation 3 given below. The value of the consistency ratio should be less than 0.1. The consistency index (CI) is given by Equation 4, and the RI is the random consistency index which depends upon the number of attributes in the matrix.

$$\text{Consistency Ratio} = \frac{\text{CI}}{RI} < 0.1 \qquad (3)$$

$$\text{CI (Consistency Index)} = \frac{\text{maximum Eigen value - n}}{n-1} \qquad (4)$$

Where ‘n’ is number of row or column in the pair wise matrix.

Table 9
Priority vector (Weights) by pair wise comparison for economic perspective in sugarcane

	A1	**A2**	**A3**	**A4**	**A5**	**A16**	**A17**	**A18**	**Eigen vector**	**Priority Vector**
A1	1.00	2.00	2.10	2.00	1.80	0.17	1.00	1.50	0.117	0.117
A2	0.50	1.00	2.00	0.25	1.30	0.25	1.00	0.20	0.060	0.060
A3	0.48	0.50	1.00	0.33	1.00	0.30	1.00	0.25	0.052	0.052
A4	0.50	4.00	3.00	1.00	2.00	0.20	1.00	2.00	0.125	0.125
A5	0.56	0.77	1.00	0.50	1.00	0.20	3.00	1.00	0.077	0.077
A16	6.00	4.00	3.33	5.00	5.00	1.00	7.00	4.00	0.384	0.384
A17	1.00	1.00	1.00	1.00	0.33	0.14	1.00	0.33	0.060	0.060
A18	0.67	5.00	4.00	0.50	1.00	0.25	3.00	1.00	0.126	0.126
Max Eigen Value = 8.9367						**CR = 0.09 <0.1 Acceptable**				

Qualitative attributes were converted into quantitative data using pair wise comparison for each of the farming practices, and its corresponding priority vector (weight) was calculated as explained above. The priority vector (weight) for the qualitative attribute is shown in Table 10.

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Table 10
Pair wise comparison of qualitative attributes (a) A16, (b) A17, (c) A18 for economic perspective with sugarcane

(a)

Stability of income over time (A16)	T1	T2	T3	Eigen Vector	Priority vector
T1	1	4	3	0.9214	0.630103
T2	0.25	1	2	0.3194	0.218423
T3	0.33	0.5	1	0.2215	0.151473
CR =0.09			Acceptable		

(b)

Independence to external agricultural inputs (A17)	T1	T2	T3	Eigen Vector	Priority vector
T1	1	7	3.2	0.9201	0.657825
T2	0.14	1	0.2	0.0998	0.071351
T3	0.31	5	1	0.3788	0.270822
CR =0.06			Acceptable		

(c)

Trade and sale opportunities (A18)	T1	T2	T3	Eigen Vector	Priority vector
T1	1	8	5	0.9759	0.7597
T2	0.12	1	1.2	0.1516	0.118
T3	0.2	0.83	1	0.157	0.1222
CR =0.08			Acceptable		

In the last step, data obtained from Tables 8, 9 and 10 were used to calculate the ranking of technology as shown in Table 11. The software uses the following Equation 5 to calculate the final ranking.

$$R_j = \sum_{ij}^{n} \rho_{ij} w_i \qquad (5)$$

Here ρ_{ij} is the normalized value taken from Tables 8 and 10, while W_i is the weight calculated from Table 9. R_j is the final rank value, so the maximum value in the row will be ranked first as shown in Table 11. Final rankings of sugarcane farming from technological, environmental and social perspectives are given in Tables 12, 13 and 14. The same methodology was followed for the calculation of the final ranking of mango and rice cropping systems, and the results obtained are presented in Figure 3.

Table 11
Ranking of all the three farming practices for sugarcane farming with the economic perspective

	W_i	**T1 (ρ_{ij})**	**T2 (ρ_{ij})**	**T3(ρ_{ij})**
A1	0.12	0.34	0.00	1.00
A2	0.06	0.00	0.00	1.00
A3	0.05	0.00	1.00	0.66
A4	0.13	1.00	0.52	0.00
A5	0.08	1.00	0.00	0.33
A16	0.38	0.63	0.22	0.15
A17	0.06	0.66	0.07	0.27
A18	0.13	0.76	0.12	0.12
Rj		0.62	0.22	0.33
RANK		1	3	2

Table 12
Ranking of all the three farming practices for sugarcane farming with the technological perspective

	W_i	**T1 (ρ_{ij})**	**T2 (ρ_{ij})**	**T3(ρ_{ij})**
A6	0.45	1.00	0.00	0.63
A7	0.16	1.00	0.00	0.33
A8	0.07	1.00	0.00	0.25
A19	0.07	0.68	0.10	0.22
A20	0.07	0.73	0.13	0.14
A21	0.10	0.72	0.10	0.19
A22	0.09	0.72	0.10	0.19
Rj		0.91	0.03	0.41
RANK		1	3	2

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Table 13
Ranking of all the three farming practices for sugarcane farming with the social perspective

	W_i	**T1 (ρ_{ij})**	**T2 (ρ_{ij})**	**T3(ρ_{ij})**
A9	0.33	1.00	0.00	0.85
A10	0.10	1.00	0.00	0.76
A11	0.14	1.00	0.00	0.40
A23	0.09	0.70	0.11	0.19
A24	0.10	0.70	0.11	0.19
A25	0.09	0.27	0.50	0.24
A26	0.08	0.19	0.56	0.25
A27	0.08	0.76	0.10	0.14
Rj		0.80	0.12	0.50
RANK		1	3	2

Table 14
Ranking of all the three farming practices for sugarcane farming with the environmental perspective

	Wi	**T1 (ρij)**	**T2 (ρij)**	**T3(ρij)**
A12	0.19	1.00	0.00	0.48
A13	0.16	1.00	0.00	1.00
A14	0.15	0.00	1.00	0.55
A15	0.11	1.00	0.00	0.22
A28	0.12	0.75	0.12	0.13
A29	0.12	0.75	0.12	0.13
A30	0.16	0.75	0.12	0.13
Rj		0.75	0.20	0.41
RANK		1	3	2

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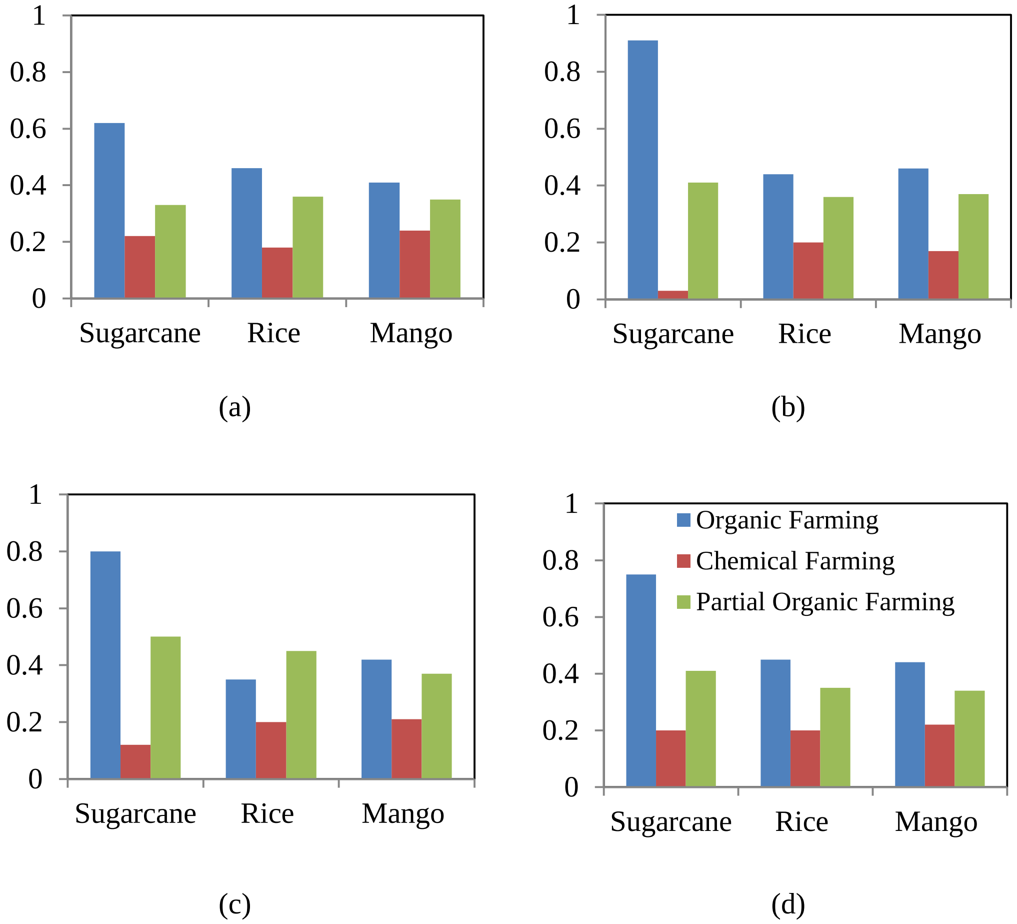

Figure 3. Technology ranking for all the crops (a) Economical perspective, (b) Technological perspective, (c) Social Perspective and (d) Environmental perspective

8. Discussion

Marketing forces, government subsidies and many other available alternatives complicates the decision making process for farmers in India. Farmers are faced with a difficult decision when selecting an appropriate resource and management practice for farming. This study illustrates how the AHP can be used to demonstrate to farmers how to reach the most appropriate solution for allocation in a particular activity. The importance of AHP as a decision support tool has been demonstrated. AHP will be helpful in policy making for various issues at the village level because of its simplicity, effectiveness and ability to deal with qualitative as well as quantitative criteria. Even though the AHP is a data intensive model, its approach is bottom up which is necessary for sustainable participatory development. It was observed that data collected from a survey like the one in this study is likely to reflect large inconsistencies. The AHP analysis demonstrated its capability of handling decision-making situations with some uncertainties and inconsistencies. In this study, AHP was applied to structure a multi-criteria prioritization (ranking) problem with the overall objective of selecting sustainable farming practices in a region with farmers as stakeholders. Through the AHP structure, participants evaluated and ranked (prioritized) three alternatives via 30 criteria. The alternatives (influencing factors) were organic, chemical and partial organic farming practices, while the major criteria

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were classified as qualitative and quantitative attributes. Both the qualitative and quantitative attributes were considered under different perspectives. The qualitative attributes included soil health, local employment, social justice, etc. The quantitative attributes considered were water requirement, soil pH, productivity etc. The options were ranked from four different points of views (called perspectives), namely economic, technological, social and environmental. The ranking of alternatives as shown in Figure 3 indicated that from the economic, technological, social and environmental perspectives, organic farming is the most suitable option for sugarcane. In rice farming, it was observed that from the economic, environmental and technological perspectives organic farming is best option, while from a social perspective partial organic was mostly preferred. In the case of the mango crop from all the perspectives, organic farming is most favorable. In all the crops, the economic perspective was most important followed by the environmental perspective. We infer that the alternatives used in farming practice should give decent returns and must be environmentally friendly. It may be difficult and impractical to shift all the farms to organic for reasons of inertia as well as anxiety expressed by farmers, etc. It was however evident from the study that such a goal may be progressively attained. Prior experience (Bhattacharyya & Chakraborty, 2005) suggests that with clear scientific evidence, strong political will and institutional support it is possible to achieve the 'fully organic' goal towards sustainable agriculture to meet the long term food and nutritional requirements in India. It was clearly evident that appropriate resource allocation in agriculture is only possible through a bottom up and participatory approach. This study also made it clear that in order for the small farming system to sustain farmers, they must resort to additional sources of income than the revenue obtained from the principal crop. The results also show that partial organic and organic farming are favorable farming practices, and the policy makers should take note.

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