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Eco-friendly Integrated Multienterprise Model for Livelihood Security in Small Farm Holdings

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1. Executive Summary

Nearly 65 percent of the Indian population is dependent upon agriculture to earn livelihood and employment. More than 50 percent of the farmers in India cultivate less than one ha (2.5 acre) land holding. To earn reasonable livelihood from such a small land holding for a family of 5-6 persons and an equal number of cattle is a debatable issue. Further, in the present scenario of increasing human and livestock populations; decreasing land to man ratio; conversion of productive agricultural lands for non-agricultural use; deteriorating natural resources (soil, water, climate and biodiversity) and decreasing total factor productivity (in single crop, commodity and enterprise based farming), a new research and development strategy is called upon to restore livelihoods of small and marginal farmers. Concerns of quality conscious society with increased demand for organic food, increasing indebtedness of farmers and associated suicides; WTO agreement and climate change trigged frequent occurrences of natural calamities like droughts and floods, heat and cold waves are other compelling reasons of a paradigm shift in our approach from single crop, commodity and enterprise based farming to multienterprise agriculture. In the past, vast synergies available with different farm enterprises remained largely under-exploited due to crop or commodity driven policies. Changing consumption and demand patterns and emerging marketing and trade opportunities are offering ample opportunities for greater diversification of agriculture systems to suit to the declining size of land holdings in India. The potential of integration of dairy, poultry, piggery, duckery, fishery, beekeeping, vermin-composting and horticulture with dominant crops/cropping systems needs to be exploited to make judicious use of farm inputs, resource management, regular income and year round employment generation on the small land holding. A comprehensive information about the multienterprise agriculture model developed at the Central Soil Salinity Research Institute (CSSRI), Karnal to improve water, nutrient and energy use efficiency in reclaimed/salt stressed environment is reported in this bulletin. Three and half years results indicated that a total gross income of Rs. 400-700/day and net income of Rs. 250-500/day can be generated from about 1.0 hectare land area when fisheries, dairy, horticulture, poultry, duckery and mushroom cultivation are integrated and byproducts of these enterprises are recycled within the system. Cultivation of vegetables on the dykes of the fish pond yielded about Rs. 100-400/week throughout the year. The model revealed that animal dung from the dairy component can be used as feed for fish, to generate biogas and electricity and to make compost to practice organic agriculture. The compost generated through decomposition of crop residues with cow dung in a series of compost pits was sufficient to meet nutritional requirement of fruit trees and vegetables planted on the dykes of the fish pond. Since no chemicals (fertilizers and pesticides) were used to grow vegetables and fruits during the study period the produce can be graded as organically produced. The experiences reveal that large scale adoption of such multienterprise agriculture will require an effective network of marketing, post harvest processing, value addition, cold chain, specialized handling and transport system, marketing intelligence, price support and export opportunities. Required research, development and policy initiatives to up-scale this kind of diversification in small farm holdings are also suggested.

2. Introduction

Continuous cultivation of rice-wheat cropping system for over four decades in Indo-gangetic alluvial plains has set in the processes of degradation in the natural resources of water, soil, climate and biodiversity. Depletion of under ground water, declining fertility status associated with multiple nutrient deficiencies, increased concentration of green house gases in the atmosphere owing to large scale burning of rice and wheat residues are some of the end results of this farming system. Most of shallow cavity tube wells (centrifugal pumps) in the Punjab and Haryana states have gone out of use consequently these being replaced with deep bore wells (submersible pumps) which cost now more than one lac rupees, which a small farmer is unable afford. Apart from these, the average land holdings continues to shrink, making profits from these crops to decrease and thus causing unsustainability and migration of farmers to urban areas and also selling of agriculture lands. Nearly 50 percent of the farmers in India cultivate less than one ha land holding. A farmer with a family of 5-6 persons and almost equal number of cattle is unable to coup-up with his daily expenditure from rice-wheat rotation. The recent National Sample Survey figures indicated that 40% farmers in India intend to quit farming. Scientific efforts made in the past to improve soil and water quality and to moderate green house gas emissions through better management of inputs and practices have not yielded tangible results to hault this degradation trend. Rice-wheat cropping system provides income to farmers only twice a year when the crops are harvested during early summer or early winter but a farmer needs regular income to meet out his day-to-day needs. This, therefore, calls for an urgent need to reorient the present ways of doing agriculture to those that can improve water productivity, increase use efficiency of nutrients and energy as well as provide regular income to meet farmers daily needs. There is also a need to reverse the natural resource degradation trend and restore the farmers' confidence in agriculture. Increasing income of the farmer per unit land and water by shifting from a crop, commodity and enterprise based agriculture to integrated multienterprise system is called for. The hypothesized mixed farming systems will also provide much needed proofing for climate change related aberrations such as drought, floods, heat and cold waves etc. Integrated farming system with multienterprise may pave the way for realizing increased productivity and profitability through integrated use of water, nutrient and energy in small farms. Multienterprise agriculture may also has the potential to decrease cultivation cost by synergetic recycling of bi-products/residues of various components within the system and also a regular source of income and employment. Keeping this in view, a multienterprise agriculture project was initiated at the experimental farm of Central Soil Salinity Research Institute, Karnal in 2006 as a model for 2.0 ha land with interdisciplinary approach. Main theme of this project was to develop farming options/capsules, which the small farmers can adopt to earn livelihood from his one or two ha reclaimed alkali land holding and also the adopted practices contribute to the reversion in degradation of natural resources. The philosophy behind multienterprise agriculture is that a farmer can adopt enterprises such as dairying, horticulture, floriculture, bee keeping, vegetable, poultry, duckery, piggery, mushroom, fisheries, gobar gas plant and solar heater etc. depending upon his resources, marketing and processing options to improve his family income and generate employment for the family at farm level.

Objectives

- ❖ Comparative evaluation of crop, commodity and enterprise diversification options in the reclaimed sodic land under small farm holding
- ❖ To increase water, nutrient and energy use efficiency through diversified agriculture systems thereby contributing to moderate predicted climate changes

- ❖ To increase farmer income by reducing cost of cultivation through recycling and better use of residues within the system
- ❖ Quantification of chemical, physical and biological changes in soil under different land-use options for improved soil health and quality
- ❖ To identify profitable, sustainable and eco-friendly agriculture model for one and two hectare reclaimed land holdings to provide livelihood security to small and marginal farmers

3. Multienterprise Model

A farming system model has been developed for 2 ha land holding with the following enterprises;

i) Agricultural crop production and horticulture on about 1.0 ha (rice-wheat, maize-wheat-moong, winter maize-soybean, pigeonpea-mustard-fodder maize) and fruits/vegetables/floriculture.

ii) Fisheries, dairy, fruits, vegetables (on dykes of the pond), fodder, poultry, duckery, mushroom, gobar gas plant and solar heater in an area of about 1.0 ha.

Before the start of the experiment, benchmark information on initial chemical, physical and biological properties of the soil was generated from different components of the model. On an average, the initial pH_2 of the cropped area was 8.1 in the upper 60 cm layer and was more than 8.5 in lower layers. The soil was low in available N, but high in P and K in all the systems. The concentrations of DTPA extractable Zn, Fe, Mn and Cu ranged from 0.85 to 2.41; 7.51 to 18.56; 5.56 to 8.40 and 0.81 to 2.18 mg kg^{-1}, respectively. The soil on the dykes of the pond towards west was highly alkaline with pH_2 10.25 and EC 4.0 dSm^{-1}, while in east direction the pH was 8.3 and EC 1.65 dSm^{-1}, respectively. The surface soil layers were sandy loam in texture and in the deeper layers clay content ranged from 19-25% throughout the depth. The surface bulk density varied from 1.5 to 1.6 g cm^{-3}. Overall, these soils are well drained with infiltration rate ranging between 5-10 mm day. Being low in organic carbon, they however, are vulnerable to dispersion and crusting especially after rain storm and are thus prone to water stagnation at times. The initial microbial biomass carbon varied from 180 to 281.1 mg C kg^{-1} soil. Soil respiration varied from 46.6 to 63.2 mg CO_2 evolved g^{-1} dry soil and specific metabolic quotient 1.9 to 3.3. Microbial nitrogen and phosphorous flush varied from 44.5 to 72.3 and 0.6 to 2.6 mg kg^{-1}, respectively. Dehydrogenase activity was in the range of 42.6 to 172.4 Mg $TPFg^{-1}$ dry soil. Similarly, acid phosphatases varied from 23.3 to 52.4 Mg $PNPg^{-1}$ dry soil.

Tentative area under pond and other components is given below :

Fish Pond 0.2 ha; animal shed 15 m x 21 m; poultry shed 7.2 x 3.7 m; duckery 3 m x 6 m; mushroom 3.5 x 6 m; gobar gas plant 7m x 6m and compost pits (4) 8.8 m x 2.1 m; 6.6 x 2.9 m; 4.5 m x 3.0 m and 2.4 m x 1.5 m

Hundred plants of banana, 28 of guava, 30 of karaunda and 30 of aonla were planted on the dykes during July-August, 2006. Inter-spaces between fruit trees on the dykes were used for raising seasonal vegetables in rotations. Almost all *kharif* and *rabi* vegetables were cultivated on the dykes during the study period. No chemical fertilizers and pesticides were used to grow fruits and vegetables throughout the study period. The compost prepared in the compost pits was enough to meet nutritional requirement of plants. The additional FYM/compost was sold at the existing market rates.

A multi-disciplinary research team representing the disciplines of agronomy, soil chemistry, soil physics, soil microbiology, soil water conservation engineering, plant physiology, animal sciences, fisheries and agricultural economics was involved in the in-depth analysis of respective components. The ultimate goal is to work out water, salt, energy, nutrient and gas exchange balance in the individual components and total system for modelling and up-scaling.

4. Multienterprise Components

Various components are the integrated parts of multienterprise agriculture model since its inception. The animals not only provide milk but they also provide dung, which is used for composting and biogas generation. The compost prepared from dung was used for improving the soil health of the pond dykes, which was used for cultivation of fruits and vegetables. Biogas generated from the dung is used for cooking and lighting. Total revenue generated, expenditure and net income from the animal products (milk+compost+biogas), fruit and vegetable on dykes, fish, poultry, ducks and mushroom on yearly and per day basis are presented in Tables 1 and 2. The revenue generation from animal products (milk+compost+biogas), fruit and vegetable on dykes, fish, poultry ducks and mushroom was Rs. 115824, 210132 and 204970 for the years 2007, 2008 and 2009, respectively. The net income from the different components was Rs. 75390, 150844 and 141196 for the last three years, respectively.

Per day revenue generation from animal products (milk+compost+biogas), fruits and vegetables on dykes, fish, poultry, ducks and mushroom was Rs. 386, 700 and 683 for the years 2007, 2008 and 2009, respectively, while the per day expenditure was Rs. 135, 198 and 213, respectively. The per day net income from different components was Rs. 251, 503 and 471 for the last three years, respectively.

Total and per day average revenue generation, expenditure and net income over the last three years (April 2007 to October 2009) from the animal products (milk+compost+biogas), fruits and vegetables on dykes, fish, poultry, ducks and mushroom is presented in Table 3. Average revenue generation, expenditure and net income from the different components were Rs. 176975, 54499 and 122477, respectively. However, per day revenue generation, expenditure and net income from the respective components was Rs. 590, 182 and

Table 1 : Year-wise revenue generation, expenditure and net income by different components

Components	Revenue generation (Rs.)			Expenditure (Rs.)			Net income (Rs.)		
	April-Dec, 07	Jan.-Dec, 08	Jan.-Oct, 09	April-Dec, 07	Jan.-Dec, 08	Jan.-Oct, 09	April Dec, 07	Jan.-Dec, 08	Jan.-Oct, 09
Milk + Compost + Biogas	104281	163748	150436	38560	47388	42454	65721	116360	107982
Fruits and vegetables on pond dykes	5923	17388	25868	-	-	-	5923	17388	25868
Fish	5620	23521	13239	1874	4390	1500	3746	19131	11739
Poultry & Ducks	-	1500	13657	-	5510	17820	-	-4010	-4163
Mushroom	-	3975	1770	-	2000	2000	-	1975	-230
Total	**115824**	**210132**	**204970**	**40434**	**59288**	**63774**	**75390**	**150844**	**141196**

408. Poultry and duckery components did not prove profitable. Per day loss was worked out to the tune of Rs 9. The net income from the mushroom component was also not encouraging.

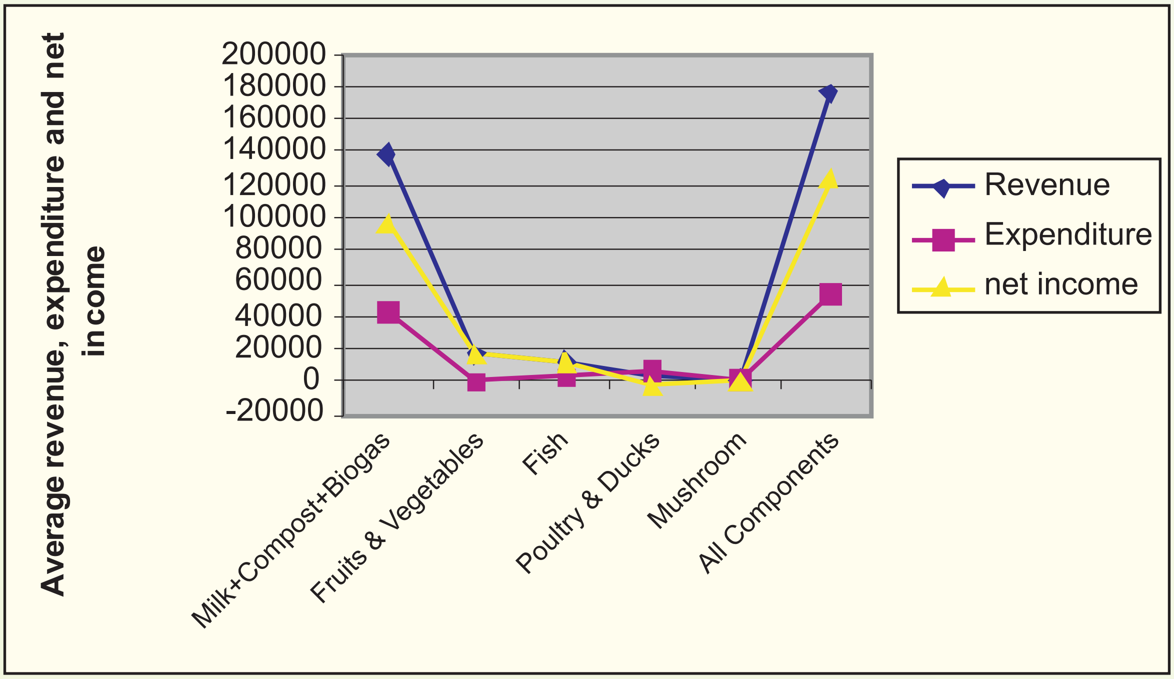
Table 2 : Year-wise per day revenue generation, expenditure and net income in different multienterprise components

Components	Per day revenue generation (Rs.)			Per day expenditure (Rs.)			Per day net income (Rs.)		
	April-Dec, 07	Jan.–Dec, 08	Jan.-Oct, 09	April-Dec, 07	Jan.–Dec, 08	Jan.-Oct, 09	April–Dec, 07	Jan. – Dec, 08	Jan. – Oct, 09
Milk + Compost + Biogas	347.60	545.83	501.45	128.53	157.96	141.51	219.07	387.87	359.94
Fruits and vegetables on pond dykes	19.74	57.96	86.23	-	-	-	19.74	57.96	86.23
Fish	18.73	78.40	44.13	6.25	14.63	5.00	12.49	63.77	39.13
Poultry & Ducks	-	5.00	45.52	-	18.37	59.40	-	-13.37	-13.89
Mushroom	-	13.25	5.90	-	6.67	6.67	-	6.58	-0.77
Total	**386.08**	**700.44**	**683.23**	**134.78**	**197.63**	**212.58**	**251.30**	**502.81**	**470.65**

Table 3 : Average and per day revenue generation, expenditure and net income over three years from April 2007 to October 2009

Multienterprise Components	Revenue generation (Rs.)		Expenditure (Rs.)		Net income (Rs.)	
	Total	Per day	Total	Per day	Total	Per day
Milk + Compost + Biogas	139488.30	464.96	42800.67	142.67	96687.67	322.29
Fruits and vegetables on dykes of pond	16393.00	54.64	00.00	00.00	16393.00	54.64
Fish	14126.67	47.09	2588.00	8.63	11538.67	38.46
Poultry & Ducks	5052.33	16.84	7776.67	25.92	-2724.33	-9.08
Mushroom	1915.00	6.38	1333.33	4.44	581.67	1.94
Total	**176975.30**	**589.92**	**54498.67**	**181.66**	**122476.7**	**408.26**

Per day returns were worked out for the months April 2007 to October 2009, about 3 years after establishment of the model. During the month, per day income came from the sale of animal products (milk+biogas+compost), vegetables grown on the dykes of the pond, fish, poultry and mushroom. The revenue generated/day from animals (milk+biogas+compost), vegetables, fishes, poultry and mushroom was around Rs.465, 55, 47, 17 and 6 respectively. The net income generated/day from animals (milk+biogas+compost), vegetable, fish and mushroom was around Rs.322, 55, 38, and 2, respectively. This income is likely to increase with the passage of time when other components like fruits, poultry, mushroom and duckery will also start yielding revenue with full potential. In addition, daily requirement of energy for cooking and electricity generation is met without incurring any additional expenditure. The Average and per day revenue generation, expenditure and net income from different components are depicted in Fig. 1.



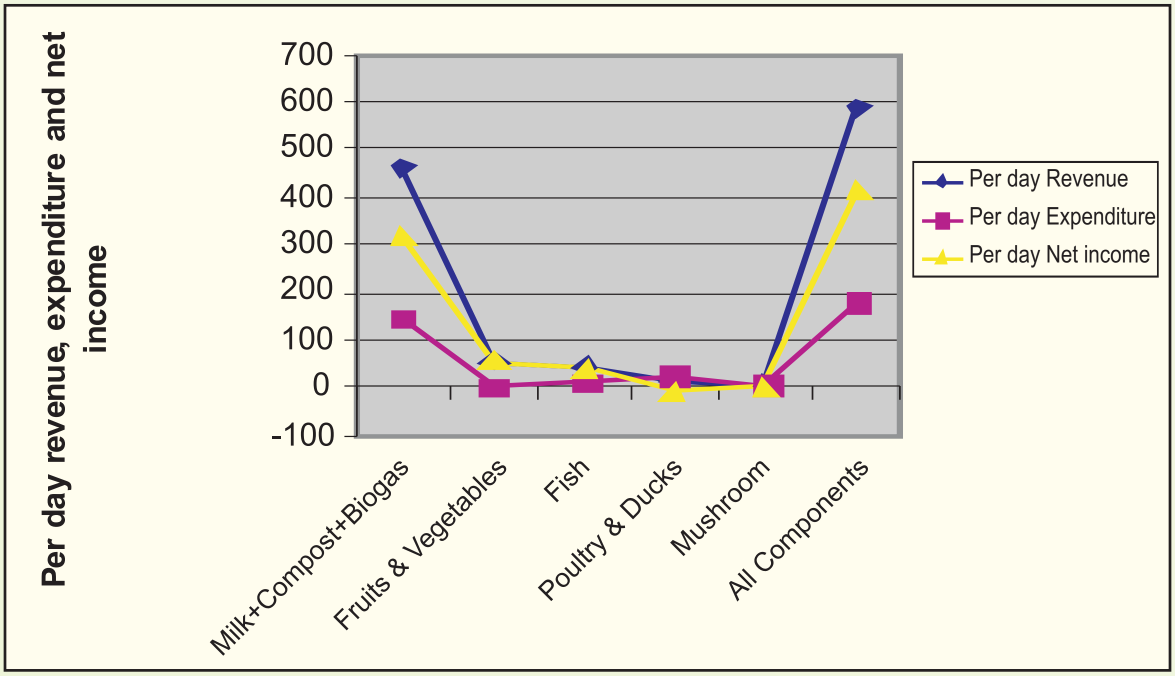


Fig 1 : Average and per day revenue generation, expenditure and net income from different components

4.1 Dairy component

Four buffaloes were purchased from National Dairy Research Institute (NDRI), Karnal on book value on April 24, 2007 for a total cost of Rs.66500/-. The total milk production from buffaloes between April 24 and May 17, 2008 was 6263.25 litres. The total income from the sale of this milk was Rs. 112834. Three cows were purchased from NDRI on October of 2007 on book value for Rs. 41943. Between October 6, 2007 to May 17, 2008, 4835 litres of milk was obtained, which was sold for Rs. 63610. Milk obtained from buffaloes and cows was sold to the staff members of CSSRI, Karnal on a concessional rate. The total revenue generation, expenditure and net income from the milk production during the study period (April 2007 to October 2009) is given in Tables 5-7. During this period one buffalo and 4 heifers were sold for Rs. 32000.

Between April 2007 and October 2009, the annual average revenue generation from the milk was Rs. 132655 (Table 4). The highest revenue was generated during the year 2008. Higher monthly revenue generation (About Rs. 18000) was observed in the month of January, February and March as compared to other months. The green fodder supply to the animals was ensured from 0.4 hectare land area marked for fodder production in which mostly berseem and oat during winter and sorghum, maize and bajra during summer were grown. The expenditure incurred on purchasing of feed, wheat straw and medicine is presented in Table 5. The average expenditure over the years was Rs. 40301. The highest expenditure was made in the months of January, February, April and June The monthly net income from the dairy component is presented in Table 6. Per day average net income from the milk production was Rs. 248 during the three years. These studies revealed that the milk production unit can be considered as 'core unit' of multienterprise, which gives regular income and employment to the farmer's family.

Healthy buffaloes of multienterprise Model

Table 4 : Monthly revenue generation (Rs.) from the sale of milk production over the years

Months	Year 2007 (Rs.)	Year 2008 (Rs.)	Year 2009 (Rs.)	Total (Rs.)	Average (Rs.)
Jannuary	-	18959	20466	39425.0	19712.50
February	-	17622	18332	35954.0	17977.00
March	-	16120	20732	36852.0	18426.00
April	1079.5	11499	17040	29618.5	9872.83
May	7153.0	10073	14326	31552.0	10517.33
June	11772.5	5635	12222	29629.5	9876.50
July	10195.8	3637	10090	23922.8	7974.25
August	10042.8	6330	7632	24004.8	8001.58
September	7777.5	15248	6843	29868.5	9956.17
October	18434.0	17328	6753	42515.0	14171.67
November	19459.0	18232	-	37691.0	9116.00
December	17617.0	19315	-	36932.0	9657.50
Total	**103531.0**	**159998**	**134436**	**397965.0**	**132655.00**

Table 5 : Monthly expenditure (Rs.) from the sale of milk production over the years

Months	Year 2007 (Rs.)	Year 2008 (Rs.)	Year 2009 (Rs.)	Total (Rs.)	Average (Rs.)
Jannuary	-	5270	4737	10007	5003.50
February	-	4800	4587	9387	4693.50
March	-	4476	5480	9956	4978.00
April	880	4275	6525	11680	3893.33
May	4015	3750	7589	15354	5118.00
June	3050	2285	4507	9842	3280.67
July	2930	1880	3965	8775	2925.00
August	3520	3620	594	7734	2578.00
September	4265	4240	1950	10455	3485.00
October	8000	4480	2520	15000	5000.00
November	6700	4920	-	11620	5810.00
December	5200	3392	-	8592	4296.00
Total	**38560**	**47388**	**43954**	**129902**	**43300.67**

Table 6 : Monthly net income (Rs.) from the sale of milk production over the years

Months	Year 2007 (Rs.)	Year 2008 (Rs.)	Year 2009 (Rs.)	Total (Rs.)	Average (Rs.)	Per day Average (Rs.)
Jannuary	-	13689	15729	29418.00	14709.00	490.30
February	-	12822	13745	26567.00	13283.50	442.78
March	-	11644	15252	26896.00	13448.00	448.27
April	199.50	7224	10515	17938.50	5979.50	199.32
May	3138.00	6323	6737	16198.00	5399.33	179.98
June	8722.50	3350	7715	19787.50	6595.83	219.86
July	7265.75	1757	6125	15147.75	5049.25	168.31
August	6522.75	2710	7038	16270.75	5423.58	180.79
September	3512.50	11008	4893	19413.50	6471.17	215.71
October	10434.00	12848	4233	27515.00	9171.67	305.72
November	12759.00	13312	-	26071.00	3306.00	110.20
December	12417.00	15923	-	28340.00	5361.50	178.72
Total	**64971.00**	**112610**	**90482**	**268063.00**	**89354.33**	**248.21**

Average monthly revenue generation, expenditure and net income are presented in Fig 2. The highest net income was recorded from January to March and after that it started decreasing till August. The net income is governed by the lactation period of the animals

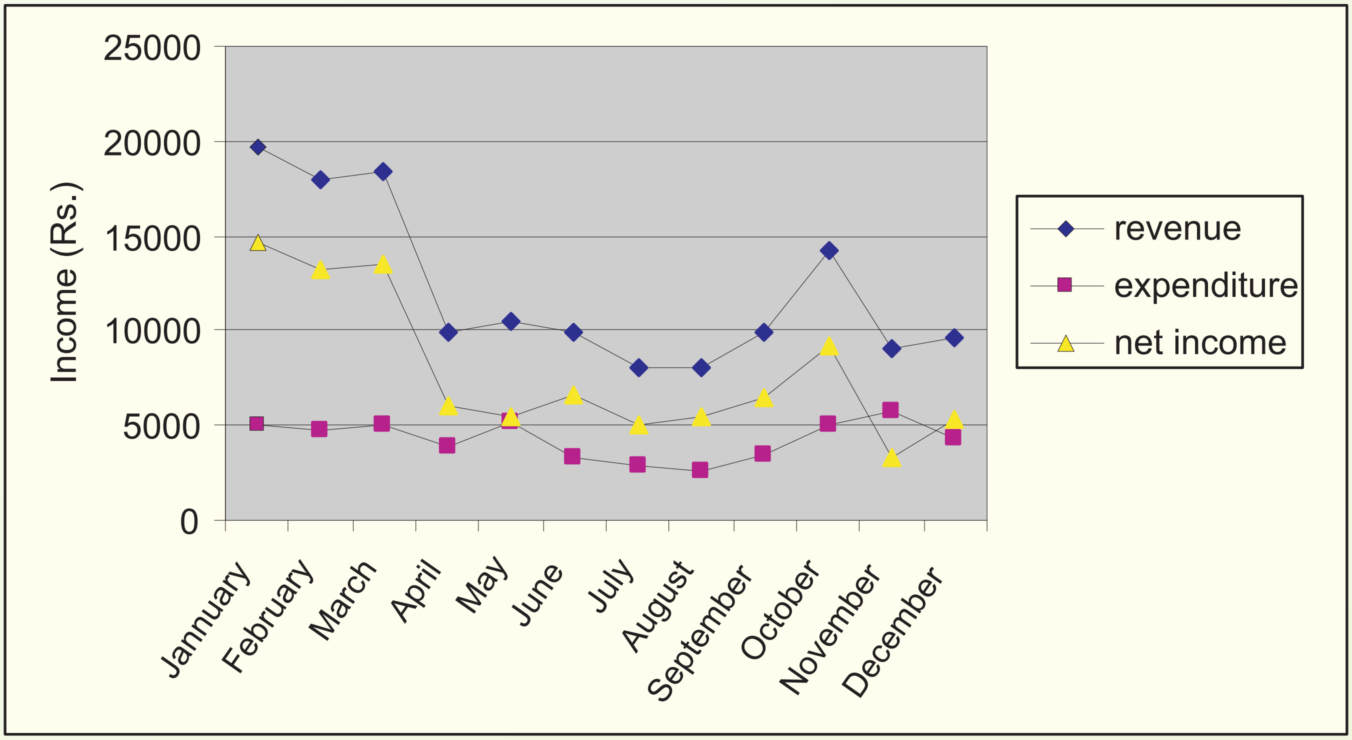


Fig 2 : Average monthly revenue generated, expenditure and net income from the milk production over the years

4.2 Vegetables and fruits production on the dykes of the pond

The raised dykes of the pond were effectively utilized for growing vegetables and fruits to meet daily food and nutritional requirement of 5-6 persons and to generate daily income to meet domestic expenditure.

On-dyke horticulture of multienterprise Model

Table 7 : Monthly revenue generation (Rs.) from fruits and vegetables grown on the dykes of the pond during 2007-2009

Months	Year 2007 (Rs.)	Year 2008 (Rs.)	Year 2009 (Rs.)	Total (Rs.)	Average (Rs.)
January	-	951	1626	2577	859.00
February	-	786	1423	2209	736.33
March	-	603	1756	2359	786.33
April	-	1167	1587	2754	918.00
May	105	1391	2770	4266	1422.00
June	206	2524	3047	5777	1925.67
July	822	2545	3697	7064	2354.67
August	654	2614	5011	8279	2759.67
September	680	1080	2515	4275	1425.00
October	1353	1057	2436	4846	1615.33
November	1144	1763	-	2907	969.00
December	959	907	-	1866	622.00
Total	**5923**	**17388**	**25868**	**49179**	**16393.00**

Fruit plants grown on dykes of the pond vegetable component are irrigated by the pond water using drip system run on solar-panel operated 1 HP pump. Per month income generated throughout the study period varied from Rs. 105 to 5011. The monthly average varied from Rs. 622 to 2760 over the years. Month-wise variations in income during 2006-07, 2007-08 and 2008-09 are given in Table 7. The fruit crops planted on the dykes started bearing fruits in 2008 (about 2 years after planting). Between August 2006 and December 2008, 252 kg of banana, 82.5 kg of guava and 7.5 kg of karaunda was produced. The average net income was Rs. 16393 over the years and it varied from Rs. 5923 to 25868. The income from fruits is likely to increase several fold during the coming years.

4.3 Poultry production

The poultry component was introduced in the last week of August 2008. The chicks numbering 120 of desi mixed breed were purchased for Rs.3000. In a period of first three months, about 91 chicks died because of some feed based infections confirmed by the poultry expert. One of the hens out of the remaining birds started laying eggs in last week of December 2008.

Healthy poultry birds feeding in the multienterprise Model

During this period, about 80 kg litter from the bedding material comprised of rice husk and excreta of poultry birds were added into the compost pit. In the year 2008, expenditure on the

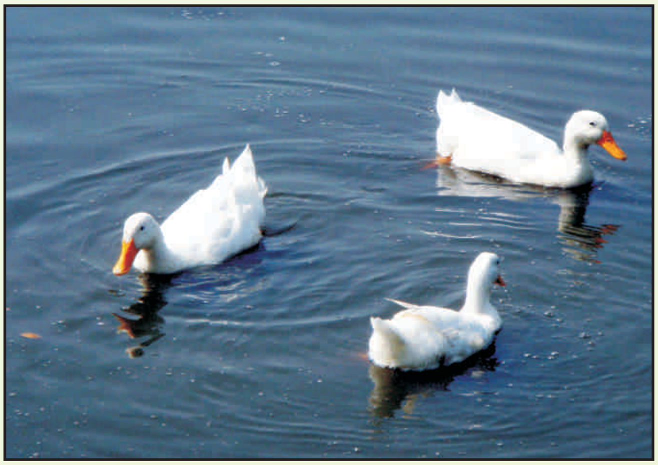
Table 8 : Economics of poultry production

Poultry production	Year 2008	Year 2009	Average
Total cost (Rs.)	5510	17820	11715.0
Gross income (Rs.)	1500	13657	7578.5
Net income (Rs.)	-4010	-4163	-4086.5
B:C ratio	-0.73	-0.23	-0.5

purchase of chicks and poultry feed was Rs.5510. The gross income was only Rs. 1500. This component incurred in a net loss of Rs. 4010. Almost similar trend was reported in the year 2009. Through poultry production the model lost Rs 4086.50 every year instead of gaining profit. In 2009, an amount of Rs. 1500/- was spent on the medicines for the poultry. Probably lack of technical expertise about the poultry production with the team resulted in poor management of poultry. The B:C ratio was always negative in poultry rearing. The economics of poultry production is presented in Table 8.

4.4 Rearing of ducks

The component of duckery was introduced from September 2008. Hundred ducks were imported from Bhubaneswar centre of the Central Avian Research Institute. Because of some feed based infection, 89 ducks died between September and November 2008.



Rearing of ducks in the fish pond has multiple benefits

At present 11 healthy ducks are remaining and started laying eggs. Rs.200 was spent on the medicines for ducks. During the day time, the ducks swim in the fish pond, which facilitate aeration and increase oxygen availability for fish. After the introduction of ducks, the mortality of fish in the pond has considerably decreased.

4.5 Mushroom production

The culture for raising mushroom as a part of the multienterprise agricultural system was prepared during October-November 2008 using wheat straw and compost. Ten kg mushroom seeds were imported from National Research Centre on Mushroom, Solan and sown in different trays. The trays were subsequently placed in environmental controlled green house made from the local materials in the farm e.g. residues of the crops, bamboo sticks etc.

The mushroom production started from November 25, 2008. Per day production varied from 0.2 to 4.4 kg and the total revenue generated per day during the study period varied from Rs. 10 to Rs. 340. During 2008 and 2009, 53 and 24 kg of mushroom was produced worth Rs. 3975 and 1770 with a total cost of Rs. 2000 each year, respectively. The net income was Rs. 1975 and -230 during 2008 and 2009, respectively with a B:C ratio of 0.99 and -0.12. In the year 2009 the model incurred the net loss of Rs. 230. Because of poor technical expertise, potential benefits could not draw from mushroom. In the coming years, mushroom productivity may increase.

Scientific Mushroom cultivation can add high commercial value to the Model

Table 9 : Productivity and profitability of mushroom production

Particulars	2008	2009	Average
Mushroom production (kg)	53.00	23.60	38.30
Total cost (Rs.)	2000	2000	2000.00
Gross income (Rs.)	3975	1770	2872.50
Net income (Rs.)	1975	-230	872.50
B:C ratio	0.99	-0.12	0.44

4.6 Fish production

Fish farming is practiced in a pond of 0.2 ha. The fish species composition was in the order of *Labeo rohita* (Rohu)-50%, *Cirrhinus mrigla* (Mrigal) -40%,*Catla catla* (Catla)-5% and *Cyprinus carpio* (Common carp) -5%. The mean weight of species recovered was 1100g of Rohu, 1250g of Catla, 800g of Mrigal, and 500g of Common carp. Besides above, 1000 number (10-50g size) fingerlings of common carp were recovered due to auto-breeding of the species.

Fishery adds multifold productivity to the Model

The partial harvesting of fingerlings was done to avoid growth competition with future stock. To increase the productivity of pond, fresh stocking of different types of advance fish fingerling was done at the rate of 10,000/ha in the month of March 2009. After eight months, the fishes had to the size of 358.0mm/700g (Catla), 376.0mm/600g (Rohu), 397.0mm/600g (Mrigal), 412.0mm/800g (Grass carp) and 286.0mm/600g (Common carp). Mean weight of fishes was around 640g. Year-wise fish production economics is presented in Table 10. The average net income and B:C ration of fish production was Rs. 11539 and 4.73 respectively. The average productivity of 0.2 ha fish pond was 236 kg/ year from.

Table 10 : Economics of fish production over the years in multienterprise agriculture model.

Particulars	2006-07	2007-08	2008-09	Average
Fish production (kg)	112.40	392.00	203.70	236.00
Revenue generation (Rs.)	5620.00	23521.00	13239.00	14126.67
Expenditure (Rs.)	1874.00	4390.00	1500.00	2588.00
Net income (Rs.)	3746.00	19131.00	11739.00	11538.67
B:C ratio	2.00	4.36	7.83	4.73

4.7 Bee-keeping

Bee-keeping is an economical enterprise that requires less investment and space. Investment is required only in the first year when system is established. As a component of the system, 25 boxes were placed in the farming system model area. The average honey production was 167.50 kg over the years. Gross income of Rs. 20793 was generated and the total cost of Rs. 12109 was incurred in production of honey. The net income of Rs. 8684 was obtained with a B:C ratio of 0.72 from the bee keeping. The comparative economics of this enterprise is presented in Table 11.

Beekeeping is the least investment component of the Model

Table 11 : Economics of honey production

Particulars	2006-07	2007-08	2008-09	Average
Honey production (kg)	343.00	106.00	53.50	167.50
Total cost (Rs.)	24165.00	9228.00	2934.00	12109.00
Gross income (Rs.)	41160.00	12660.00	8560.00	20793.33
Net income (Rs.)	16995.00	3432.00	5626.00	8684.33
B:C ratio	0.70	0.37	1.92	0.72

4.8 Productivity and economics of the cropping systems

Economics of various components across the enterprises was computed using standard methodology, the labour component was discounted. This is mainly because the model is developed for small and marginal land holders who can deploy 3-4 family members for routine operations. Also the model is closely integrated with domestic activities, so the labour requirement is minimum. The economic analysis of raising different crops is presented in Table 12. The results showed that wheat cultivation was more profitable compared to the rice cultivation. Amongst the different enterprizes studied, the fodder crops gave the highest B:C ratio of 5.89 and 4.17 in berseem and oat, respectively. The highest net income was reported under bottleguard cultivation (Rs. 45933.88/ha) followed by wheat and berseem (Rs. 42664.53 and 38583.00/ha, respectively). The operational cost of fodder crops, in general, and Berseem (Rs. 7313/ha) in particular was much lower than the grain crops. Performance of pigeonpea, soybean, gladiolus and greengram was not satisfactory and proved uneconomical at the existing pattern of resource use. Several factors contribute for variation in economic analysis of each crop each year. The pooled analysis after 5 years will give clear picture of different capsules of this 2 ha model. Variations in the economics of fruits, vegetables and flower crops due to fluctuating market prices and availability of such produce at different times of the year. This study also provides an additional opportunity to judge the marketing behaviour of different crops and enterprizes being tried in the model.

Table 12 : Average value of economics of crops grown during 2007-08 and 2008-09 (Rs./ha) in multienterprise model

Crops	Operational Cost (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)	B:C Ratio
Rice	20623.63	50825.00	30201.38	2.51
Wheat	15485.48	58150.00	42664.53	3.38
Winter Maize	15884.75	32345.00	16460.25	1.66
Green gram	10290.13	14897.50	4607.38	0.95
Soybean	14166.30	15632.00	1465.70	0.64
Pigeonpea*	11270.35	750.00	-10520.35	0.07
Mustard	8106.30	14598.25	6491.95	1.40
Baby corn	19869.90	49975.39	30105.48	2.01
Cabbage	11881.25	20392.50	8511.25	1.44
Cauliflower	20749.63	33500.00	12750.38	1.26
Chillies*	6826.00	10000.00	3174.00	1.46
Bottle gourd	33643.63	79577.50	45933.88	2.35
Gladiolus	42085.00	59080.77	16995.77	0.91
Marigold	14556.09	26446.15	11890.07	1.22
Berseem	7317.00	45900.00	38583.00	5.89
Oat*	8400.50	35000.00	26599.50	4.17
Maize fodder	9707.13	24000.00	14292.88	2.19
Maize+ Cowpea (Fodder)*	10351.50	22500.00	12148.50	2.17
Sorghum+ Cowpea (Fodder)*	8889.95	24000.00	15110.05	2.30

** Based on 2007-08 data*


Rice-wheat is a grainery source for the small and marginal farmers of the Model

The productivity in different cropping systems was worked out keeping in view the quantity of marketable produce from 2007-08 and 2008-09. The productivity in the case of fodder crops represents the green fodder yield, in grain crops it is the grain yield and in the case of vegetables and fruits it was the green vegetable and fresh fruit production. In the case of fodder production, the highest system productivity was recorded with maize-oat-berseem (170.86 t/ha), followed by sorghum-berseem (147.50 t/ha) cropping system. Under crop production components, rice-wheat cropping system registered the highest system productivity (10.98 t/ha) in terms of grain production in comparison to other cropping systems. In other cropping systems some crops were used as green manuring and some as fodder, so comparison between system productivity was not possible among the cropping systems. Under flower production system, 2.34 t/ha productivity of baby corn was recorded, besides 5484 sticks of gladiolus and 1.13 t/ha flowers of marigold. The average sunflower yield for two years was 1.91 t/ha during both the years. Two systems of the vegetable production i.e. Ladies finger/cabbage-tomato-tomato/cucumber and Ladies finger-cauliflower-bottleguard were raised in the field. In these two systems, the highest productivity was in Ladies finger-cauliflower-bottle guard (9.04 t/ha), considerably higher in comparison to Ladies finger/ cabbage-tomato-tomato/ cucumber (8.86 t/ha).


Flower and vegetable components ensure regular income to the farmers

Fruit crops and associated intercrops provide insurance cover to the Model

Land-scape of different crop components laid for the Model

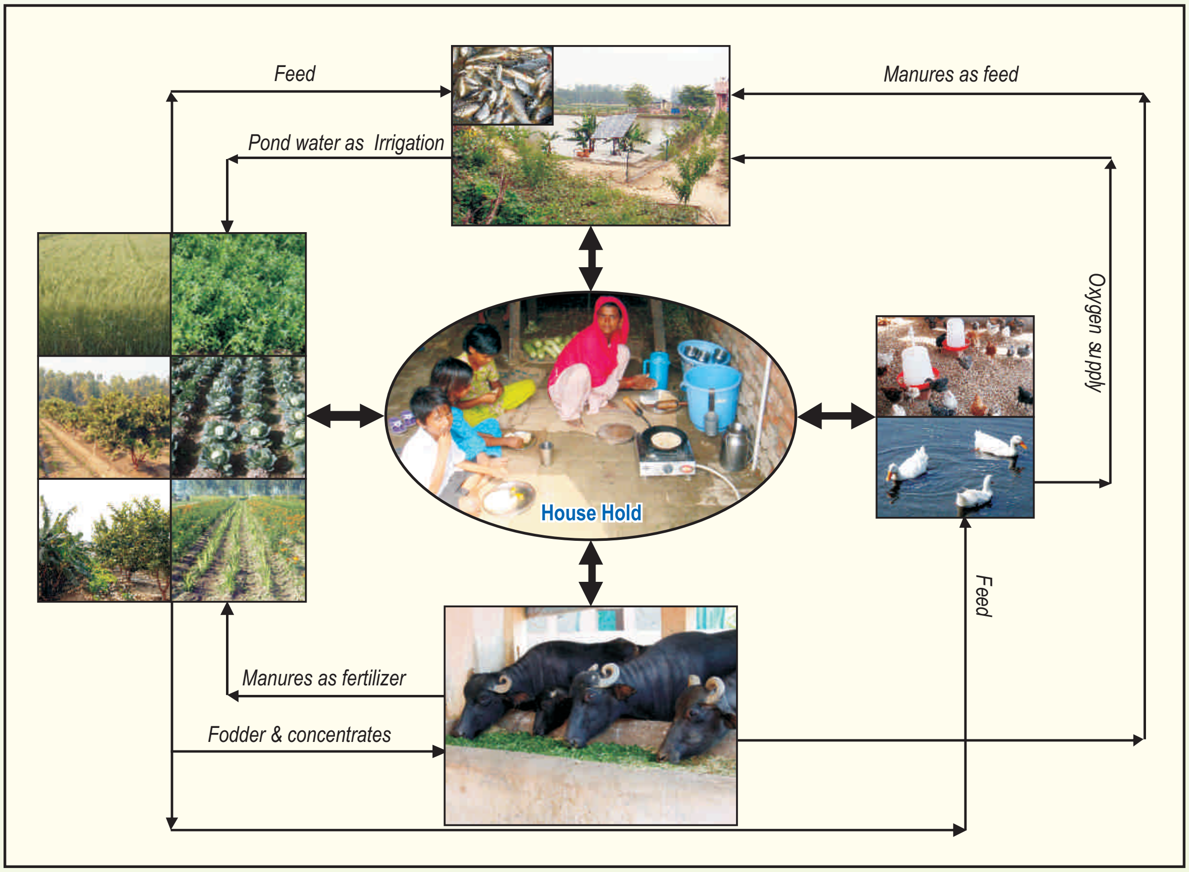
The economics of the different cropping systems was calculated for the year 2008-09 in the multienterprise agriculture model (Table 13). The highest net income (Rs. 108060/ha) was observed with horticulture based production system with a B:C ratio of 5.19 followed by fodder production system (4.93) and grain production (2.36) systems. In floriculture and vegetable production, more or less same B:C ratio was obtained. Horticulture based system in which the vegetable crops were cultivated with the fruit plants of guava and papaya, proved to be economic and highly beneficial to the farmers.

Table 13 : Economics of different cropping systems during 2008-09

Components	Operational cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B:C ratio
Fodder production	11337.25	67300.00	55962.75	4.93
Grain production	29210.67	97518.00	68307.33	2.36
Floriculture production	28558.70	82673.47	55114.77	1.99
Horticulture based system	20836.25	128896.30	108060.00	5.19
Vegetable production	18840.75	53888.75	35048.00	1.86

5. Recycling of Resources

The resources were recycled within the system to increase water, nutrient and energy use efficiency through diversified agriculture options. The animal, fishery, poultry and duckery components are getting the feed and fodder from the crop components. Whatever dung is produced by the animals is used in different ways. Major part of it goes for composting and used for application in fruits and vegetables being cultivated on pond dykes. Some part of it is used for biogas generation to meet the daily energy requirement of kitchen for an average family and remaining part of it goes in fish pond as 'feed' for fishes. Nutrient rich pond water is used for irrigating the crops around the pond and in the crop field during summers. Banana leaves, over matured fruits and vegetables are also used as fish feed. All the resources are being recycled within the system. Feed Concentrates for the animals also come from the crop component. Animal feed is prepared at site to reduce the cost of inputs and to ensure the quality of the feed.



Recycling resources in multienterprise agricultural model

5.1 Recycling of FYM within the system

About 133.42 t of cow dung was obtained from the five to seven animals during the study period. Out of which, 81.32 t was used for generating biogas, 40.94 t for composting, 4.54 t for vermin-composting and 6.62 t was added in the fish pond as fish feed (Table 14). The dung used in biogas plant, after production of biogas was also added into the compost pits. A major part of urine of animals was added directly into the fish pond.

Gobar gas plant was established in August 2007. The cooking gas production started from September 2007. Bio-gas obtained from the plant is adequate to meet the daily cooking needs of a family of 5-6 people. The cooking gas was available throughout the year to meet energy and electricity needs. As an alternate/ supplement to the commercial electricity supply, three electric lamps (40 w) can also be lighted using cooking gas to meet electricity need. Total expenditure on establishment of gobar gas plant was Rs. 12000. The government provides subsidy to the extent of 50 to 75% to the farmers for establishment of this facility at their farms.

Gobar gas helps fulfill the domestic energy requirements

Table 14 : Monthly dung production (tonnes) and its recycling in the system during 2007-09

Month	Gobar gas plant (t)	Compost pits (t)	Vermi-compost (t)	Pond (t)	Total (t)
April 2007	0.50	-	-	-	0.50
May	2.20	-	-	-	2.20
June	2.80	-	-	-	2.80
July	2.70	-	-	-	2.70
August	2.80	-	-	-	2.80
September	2.70	-	-	-	2.70
October	4.80	-	-	-	4.80
November	5.60	-	-	-	5.60
December	6.00	-	-	-	6.00
January 2008	2.20	1.80	-	2.20	6.20
February	2.10	1.50	-	2.30	5.90
March	3.50	1.40	0.41	0.40	5.71
April	2.50	1.90	-	-	4.40
May	1.30	1.30	0.16	0.16	2.92
June	2.10	0.40	0.46	0.25	3.21
July	1.60	1.20	-	0.01	2.81
August	1.70	1.00	-	-	2.70
September	3.20	2.00	0.69	-	5.89
October	4.00	2.50	-	0.12	6.62
November	2.60	2.30	-	0.30	5.20
December	2.10	2.18	0.435	0.20	4.91
January 2009	2.36	2.10	-	-	4.40
February	2.10	1.94	-	0.16	4.19
March	2.10	1.98	0.81	-	4.89
April	2.13	2.41	-	0.05	4.59
May	2.22	1.62	0.445	0.30	4.58
June	2.10	2.36	-	-	4.42
July	2.26	2.40	-	-	4.66
August	2.28	1.68	0.76	-	4.72
September	2.45	2.28	-	0.18	4.91
October	2.38	2.75	0.37	-	5.49
Total	**81.32**	**40.94**	**4.54**	**6.62**	**133.42**

6. Quality of the Soil on Pond Dykes

Soil quality parameters are regularly studied since the beginning of the model establishment. Average soil quality parameters (0-120 cm depth) after three years of model establishment are compared with their initial values in Table 15. Soil used to raise the pond dykes is being used for cultivation of fruits and vegetables. In the beginning available sodic soil (pH 10.25 and EC 4.0 dS/m) was used for dyking the pond.

Table 15 : Average values (0-120 cm depth) of soil quality parameters

Soil	pH	EC (dS/m)	OC (%)	Available nutrients (kg/ha)		
				N	P	K
In the beginning (2006)	10.25	4.00	0.14	55.25	15.00	213.54
After three year (2009)	9.56	1.19	0.19	59.28	15.13	238.13

The soil was poor in organic carbon (0.14 %) and available nutrients (55.25 kg N, 15.00 kg P and 213.54 kg K) due to high pH. High pH induced dispersion of soil particles made it difficult to establish the dykes. The dykes were continuously subjected to vegetation that tolerate sodicity and help stabilize the dykes. Fruit trees and vegetables were preferred so that the regular income can be earned besides stabilizing the pond dykes. Though the yields of these crops on dykes were low in the beginning, the major benefit was achieved in terms of stable pond dykes and improved soil quality. At present (after three years) the pH and EC of the soil on pond dykes reduced considerably and improvement has been observed in organic carbon and available nutrient status. Though the soil quality at present is not very good, yet there is overall improvement in quality parameters. Continuation of the model will bring significant improvement in soil quality parameters in future.

7. Soil Health and Quality

7.1 Soil physical quality

Depth-wise soil samples were collected to study important soil physical properties in October 2009. Samples were collected from 0-15, 15-30 and 30-60 cm soil layers. Bulk density was determined by core method. Undisturbed soil cores were collected for determining saturated hydraulic conductivity in the laboratory by constant head method. Water retention at 33 and 1500 kPa was studied by a pressure plate apparatus. Soil bulk density ranged between 1.41 and 1.44 Mg m^{-3} in various depths across the production components (Table 16). In general, bulk density was higher in the deeper layers as compared to the surface. Though the variation in bulk density values was not considerable, yet the fodder production component recorded lower bulk density values as compared with the other components in all the depths. Saturated hydraulic conductivity varied between 1.4 and 2.0 cm h^{-1} among the depths across the production components. Fodder plots recorded 2.0 and 1.8 cm h^{-1} saturated hydraulic conductivity values, numerically higher than all the other production components. Because of the higher clay content and bulk density, the saturated hydraulic conductivity values in lower layers were lower than the surface layer. Water retained at 33 and 1500 kPa soil-water suction also iterated the same trend as that of bulk density and hydraulic conductivity. Fodder production components had higher available water as compared to the other production components in all the depths. This indicates that the fodder production component is highly efficient in storing moisture and its availability for the plant growth.

7.2 Soil chemical quality

Net increase in available nitrogen and phosphorus was observed in all the cropping systems (Table 17). Regular nitrogen build-up was the result of integrated nutrient management in all the cropping systems. Higher nitrogen build-up in fodder production system as compared to others was the result of irrigation with pond water. Nutrient balance in most of the cropping systems was positive, more so in the case of N, P and micronutrients. Recycling of farm wastes and use of pond water helped improving the soil chemical health. The improvement seems to be slow but steady.

Table 16 : Important soil physical properties under different production components

Production components	Soil depth (cm)	Bulk density (Mg m^{-3})	Sat. Hydr. Cond. (cm h^{-1})	Water retention (cm^3 cm^{-3}) at		Available water (cm^3 cm^{-3})
				33 kPa	1500 kPa	
Fodder Production	00-15	1.39	2.0	0.30	0.17	0.13
	15-30	1.41	1.8	0.29	0.17	0.12
	30-60	1.41	--	0.30	0.16	0.14
Grain Production	00-15	1.42	1.8	0.24	0.15	0.09
	15-30	1.43	1.4	0.25	0.14	0.11
	30-60	1.44	--	0.24	0.14	0.10
Floriculture Production	00-15	1.42	1.7	0.25	0.14	0.11
	15-30	1.43	1.5	0.23	0.14	0.09
	30-60	1.43	--	0.22	0.14	0.08
Horticulture Production	00-15	1.43	1.7	0.25	0.14	0.11
	15-30	1.43	1.8	0.24	0.14	0.10
	30-60	1.43	--	0.22	0.13	0.09
Vegetable Production	00-15	1.41	1.8	0.25	0.16	0.09
	15-30	1.43	1.6	0.24	0.15	0.09
	30-60	1.44	--	0.23	0.15	0.08

Table 17 : Fertility status of different cropping system under multi enterprise agriculture

Cropping systems	Year	pH	EC (dS/m)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
Fodder production	Initial	8.18	0.35	103.50	26.75	301.50	1.90	13.35	6.15	1.64
	1st yr	8.17	0.37	129.00	27.00	288.00	1.74	11.85	6.45	1.58
	2nd yr	7.91	0.30	216.50	28.90	291.50	1.80	10.44	10.03	1.55
Grain production	Initial	8.32	0.28	106.00	24.83	300.00	1.65	14.05	5.88	1.36
	1st yr	8.27	0.28	128.25	24.70	286.25	1.59	12.35	6.07	1.45
	2nd yr	8.05	0.25	180.75	26.38	267.00	1.69	13.43	7.57	1.46
Floriculture production	Initial	8.29	0.25	108.00	23.50	388.50	1.78	13.25	6.61	0.81
	1st yr	8.16	0.29	136.50	23.80	377.50	1.79	12.40	6.69	0.84
	2nd yr	8.10	0.29	183.50	27.10	321.00	2.63	10.05	8.12	0.71
Horticulture based production	Initial	7.70	0.46	123.00	24.20	409.00	2.41	17.80	8.40	7.70
	1st yr	7.74	0.46	131.00	25.10	364.00	1.91	17.50	8.10	7.74
	2nd yr	7.44	0.32	205.00	30.40	345.00	1.21	12.78	11.04	7.44
Vegetable production	Initial	7.70	0.46	123.00	24.20	409.00	2.41	17.80	8.40	2.18
	1st yr	7.57	0.31	144.00	30.40	381.00	1.95	15.20	8.31	1.94
	2nd yr	7.44	0.28	201.00	29.40	305.00	1.38	10.20	8.64	1.80

7.3 Soil biological quality

The microbial properties like microbial biomass carbon, microbial nitrogen, dehydrogenase activity and acid phosphatase activity were determined initially and after two years of experimentation using standard methods under different cropping systems to study the effect of different cropping systems on microbiological properties of semi- reclaimed alkali soil.

After 2 years of cropping greater microbial biomass carbon (mg kg^{-1}) was observed under fodder maize-pigeonpea-mustard (287.3/187.1); sorghum-berseem (269.3/248.6); soyabean-winter maize (255.2/231.1); moong-maize-wheat (194.5/168.7and vegetables only (185.2/179.5) mg kg^{-1}. In rice-wheat (227.3/ 255.6) and fruits + vegetables (152.2/180.2) cropping systems lower MBC was recorded whereas, least MBC was recorded in floriculture system (142.5/194.8). Similarly trend was observed under microbial nitrogen flush except Fruit + vegetable system (Table 18). The highest was observed under fodder production (58.5/39.6 mg kg^{-1}), whereas the lowest was under floriculture (15.6/16.5 mg kg^{-1}) system.

The mean dehydrogenase activity was greater under legume crops except winter maize-soyabean system. The maximum DHA was observed under sorghum–berseem (145.2/59.9 µg TPF g^{-1} soil) followed by Moong-maize-wheat (124/16.8 µg TPF g^{-1} soil). The activity was comparatively greater under vegetable

Table 18 : Mean initial values of microbiological properties and values after two years of experimentation in multienterprise project.

Cropping systems	Microbial biomass carbon (mg kg^{-1})	Microbial nitrogen flush (mg kg^{-1})	Dehydrogease activity (µg TPF g^{-1} soil)	Acid phoaphatase activity (µg PNP g^{-1} soil)
Grain production				
Rice-wheat	255.6 ± 40.6 (227.3 ± 36.3)	18.5 ± 3.2 (17.7 ± 5.0)	24.6 ± 3.2 (58.6 ± 11.1)	184.5 ± 12.5 (379 ± 13.1)
Moong-maize-wheat	168.7 ± 10.2 (194.5 ± 30.9)	19.8 ± 2.5 (20.5 ± 1.1)	16.8 ± 2.9 (124.0 ± 17.8)	103.5 ± 18.7 (329.2 ± 21.1)
Soyabean-winter maize	281.1 ± 45.6 (255.2 ± 41.5)	16.3 ± 3.1 (26.9 ± 1.5)	58.9 ± 4.3 (55.8 ± 10.1)	150.2 ± 16.1 (312.8 ± 21.3)
Fodder maize-pigeonpea–mustard	187.1 ± 19.2 (287.3 ± 35.2)	16.5 ± 2.5 (29.8 ± 2.4)	45.4 ± 8.9 (74.7 ± 17.2)	219.5 ± 17.7 (337.0 ± 19.9)
Fodder production				
Sorghum-berseem	268.6 ± 23.5 (269.3 ± 28.6)	19.6 ± 3.6 (38.5 ± 5.8)	59.9 ± 6.0 (145.2 ± 20.3)	91.3 ± 7.7 (350.0 ± 14.9)
Fruits + vegetables				
(Guava + papaya + tomato + ladies finger)	180.2 ± 15.6 (152.2 ± 23.4)	18.9 ± 2.2 (20.8 ± 3.8)	21.9 ± 2.4 (67.7 ± 5.2)	121.6 ± 16.2 (260.2 ± 20.3)
Vegetables				
(Bottle guard-Cauliflower/Cabbage	179.5 ± 25.2 (185.2 ± 19.5)	17.6 ± 3.9 (22.2 ± 4.2)	24.6 ± 3.5 (77.3 ± 6.2)	105.7 ± 15.4 (355.7 ± 18.2)
Floriculture				
(Baby corn-marigold –gladiolus	194.8 ± 19.1 (142.5 ± 25.3)	16.5 ± 1.9 (15.6 ± 2.1)	21.2 ± 2.6 (66.5 ± 9.8)	134.4 ± 9.2 (257.9 ± 15.7)

* *The values after two years are presented in parenthesis*

alone system compared to Fruits + vegetables and floriculture system which may be because, vermin-compost is continuously being added in the vegetable crops. Rice- wheat and winter maize-soyabean showed the minimum dehydrogenase activity. After 2 years, acid phosphatase activity was almost similar under all the cropping systems except fruits + vegetable and floriculture system which showed minimum activity. After 2 years the results showed that fruits + vegetables and floriculture system had lower microbial properties. However, to come out with definite trend of cropping systems on microbial properties, more observations are to be needed in the coming years when the cropping systems get stabilized.

Microbial quality of the compost

Total number of bacteria, actinomycetes and fungi were determined after every 15 days interval from 15 to 90 days in a compost pit of size (8 x 5 m and ½ m deep). The pit was mixed with cow dung, biogas slurry and vegetables wastes and fallen leaves. The total microbial count and C:N ratio of the compost at different intervals shown in Table 19.

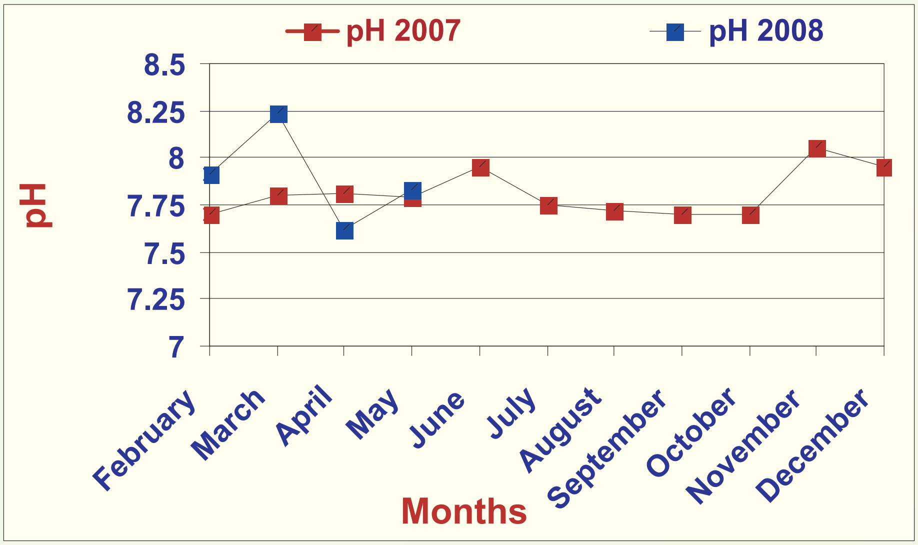
The results thus showed that the number of bacteria after 15 days of composting were 16.1 x 108 which reduced to the level of 2.0x 106 after 90 days of composting. Numbers of actinomycetes were 7.85 x 106 and reduced to the level of 2.7 x 101 and number of fungi which were 11.6 x 105 after 15 days and after 90 days it was decreased to 1.3 x 101. All the microorganisms decreased with the passage of time may be because of very high temperature (60-650C) when the compost is finally prepared which might have killed the microorganisms. The maximum survival was of bacteria might be due to development of thermophilic in nature. Similarly C:N ratio also decreased from 15.94 at 15 days to 10.47 after 90 days of composting when the compost was almost ready to use in the field.

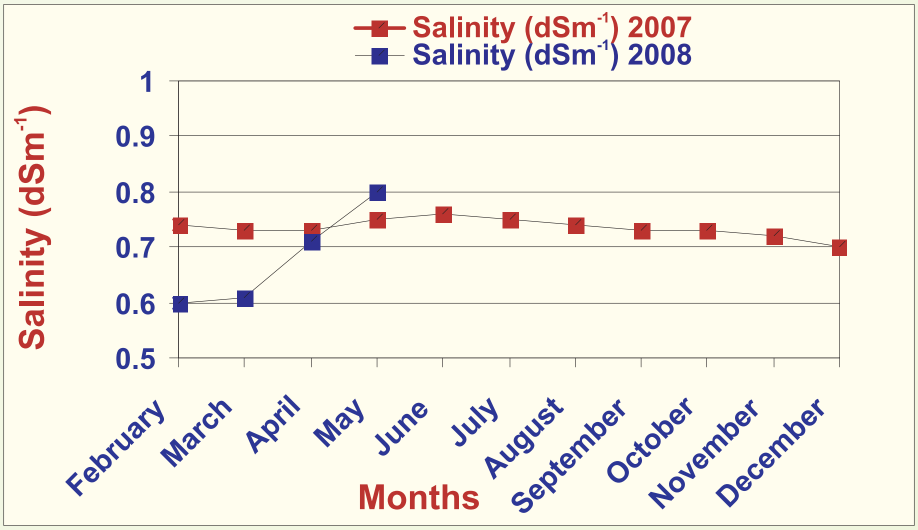
Table 19 : Microbial count and C:N ratio in a pit at different intervals

Sampling days	Bacteria	Actinomycetes	Fungi	C:N ratio
15	16.1 x (10^8) $\pm$ 1.3	7.85 x (10^6) $\pm$2.63	11.6 x (10^5) $\pm$2.14	15.94
30	17.7 x (10^8) $\pm$ 0.58	6.6 x (10^6) $\pm$1.22	10.2 x (10^5) $\pm$ 1.04	14.97
45	19.9 x (10^6) $\pm$ 3.73	10.3 x (10^4) $\pm$ 2.76	10.5 x (10^4) $\pm$ 0.25	12.37
60	4.5 x (10^6) $\pm$ 1.04	11.0 x (10^4) $\pm$ 3.03	5.4 x (10^3) $\pm$ 1.25	11.61
75	2.1 x (10^6) $\pm$ 0.46	4.7 x (10^3) $\pm$ 2.08	2.5 (10^1) $\pm$ 0.5	10.32
90	2.0 x (10^6) $\pm$ 0.53	2.7 x (10^1) $\pm$ 0.62	1.3 x (10^1) $\pm$ 0.05	10.47

8. Water Quality in the Pond

The monthly variations in pH2, EC and salinity of water in the fish pond were monitored during the study period. The pH2 ranged from 7.6 to 8.3; EC from 0.6 to 0.8 dS/m and total dissolved salts from 380 to 520 me/L. These values were well within the prescribed safe limits for fish culture in ponds (Fig. 3). Water quality parameters studied from the pond are presented in Table 20. These water quality parameters are very crucial for fish growth and productivity. Water quality parameters observed in the pond are in the safe limits for the fish health and production.





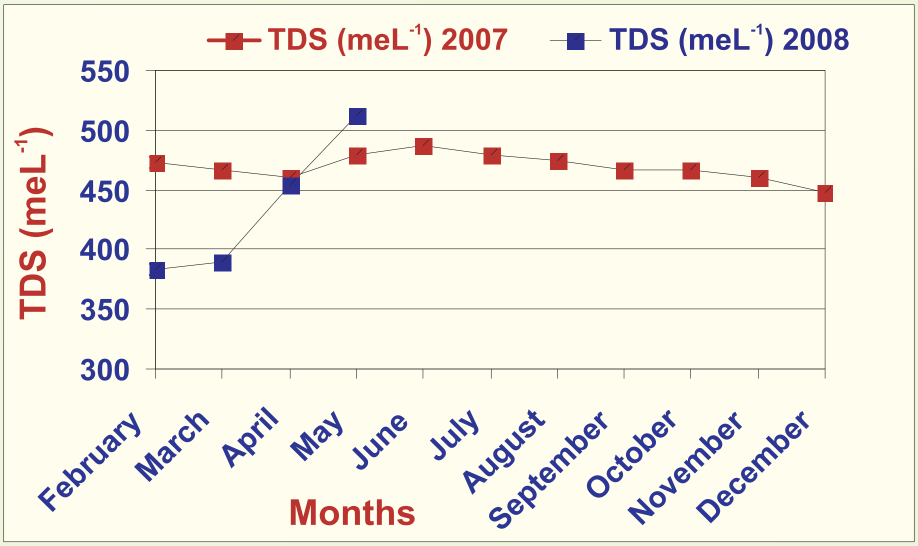


Fig. 3 : Monthly variations in pH, EC and salinity of the water in fish pond during 2007 and 2008

Fish pond : The most important component of the Model

Table 20 : Water quality parameters of the fish pond

Parameters	Values
Pond water area (ha)	0.20
Mean water depth (m)	1.25 (Range-0.90-1.50)
Water transparency (cm)	10-15
Water pH	7.50-8.90
EC(dS/m)	0.65-0.82
Water temperature (°c -max. range only)	27-41
Planktonic productivity(ml)/100-L water	0.50-1.50

8.1 Use of fish pond water for crop production

The fish pond water gets enriched in nutrients and its quality can be rated as very good. This water was used in cropping system component. Besides a source of irrigation it helps in improving soil fertility. The chemical composition of fish pond water is presented in Table 21.

Table 21 : Chemical composition of fish pond water

Characteristics	pH	EC (dSm^{-1})	NH_4-N ($mg\ L^{-1}$)	NO_2-N ($mg\ L^{-1}$)	NO_3–N ($mg\ L^{-1}$)	P ($mg\ L^{-1}$)	K ($mg\ L^{-1}$)	Zn ($mg\ L^{-1}$)	Fe ($mg\ L^{-1}$)	Mn ($mg\ L^{-1}$)	Cu ($mg\ L^{-1}$)
Values	8.1	0.72	0.82	0.28	1.98	0.25	0.62	0.11	0.15	0.12	0.03

9. Water Balance of the Pond

Comprehensive information on the pond water balance is monitored since inception of the model. Water balance studies were carried out in the fish pond to enhance the water productivity (Tables 22 and 23). Evaporated water is actually lost, while seepage loss could be recovered and for this only pumping cost is required. The seepage rate varied with the depth of water in pond. Actual effective loss of water was mainly through evaporation and this varied with the months. Higher productivity of pond could be achieved when depth of pond varied between 1 to 1.5 m.

Table 22 : Yearly water balance of the pond in the year 2008

Loss of water due to seepage	3329 M^3
Water loss due to evaporation	2254 M^3
Rain fall	1604 M^3
Water storage of pond	2621 M^3
Water added by the tube well	6900 M^3

Table 23 : Monthly water balance of the pond for enhanced water productivity

Month	Rainfall (mm)	Pan evaporation (mm)	Actual pond evaporation*
January	20.00	35.65	28.52
February	15.80	56.84	45.47
March	42.63	104.47	83.57
April	11.71	198.00	158.40
May	22.15	255.75	204.60
June	75.78	212.10	169.68
July	265.45	143.22	114.57
August	196.40	121.52	97.21
September	65.46	102.90	83.32
October	13.81	76.57	61.25
November	10.87	65.70	52.56
December	13.73	41.85	33.48

**Considering pan coefficient as 0.80*

10. Resource and Energy Conservation for Environmental Quality

Besides a source of regular income to the small and marginal farmers, the multienterprise model acts as the most vital technology in conserving farm resources and energy. Recycling of farm wastes and other byproducts of the components ensures environmental quality. Intensive observations are being recorded on the components of water balance in and around the pond as well as irrigation command of the pond. Water balance components will provide precise information on the water requirement of the individual enterprise as well as the components. Future water management strategies will be based on the judicious use of available water resources in the model at farm-level. Gobar gas plant is an integral component of the model and the most important energy resource for domestic uses. Information on energy fluxes for cooking and electricity generation is being gathered to estimate energy budgets to fully or partly fulfill the farm energy requirements. Electricity generation by harnessing the solar energy is also practised in the Model. At present the fruit crops grown on the dykes and vegetables grown in the vegetable component are irrigated by drip irrigation system. The drip irrigation system is run on solar energy system. Resource recycling and physico-chemical transformations involve gas exchange within and across the multienterprise components. Precise observations are being recorded to compute the gaseous fluxes across the model components. The above information will provide deep insight into energy balance at farm-level. Conservation and judicious use of farm resources in multienterprise model will ensure environmental quality and help restore the ecosystem sustainability. Intense and perennial vegetation on and around the pond dykes as well as different crop components of the model help in sequestration of considerable carbon pools.

11. Up-scaling and Commercialization of Multienterprise Model for Enhanced Productivity

Success of a technology depends on its adoption by the end-users. Multienterprise model of CSSRI has a great potential for up-scaling and commercialization because of its suitability to small and marginal land holders. As a first step, efforts are being made to demonstrate the model on farmers' fields. Presently the model is demonstrated on six locations in different agro-climatic regions. Beginning of the demonstrations is highly encouraging. Government of India is already providing subsidy on the most of the components of the model, which attracts the attention of resource poor small and marginal farmers. The model can be up-scaled and commercialized by its integration with many of the governmental scheme e.g. NREGA, RKVY, IRDA, Food Security Mission etc. Besides rural developmental schemes, other governmental programmes related to fisheries, poultry, non-conventional energy, rural electrification, rural sanitation etc. can be easily linked with the model. Options and provisions for value addition, processing facilities, good marketing network and integration with other rural enterprises can help attract the attention of rural youth. Special training programmes for skill upgradation among the rural masses in general; and youth and women entrepreneurs in particular can help in rapid up-scaling of the model. CSSRI Karnal can act as a nodal institution for conducting such trainings. Formation of user groups, self-help groups and involvement of non-governmental organization may help in commercialization of the model in target areas. In its present form, the model has full potential to earn regular livelihood for small and marginal farmers by ensuring food and nutritional security besides its socio-economic and ecological benefits. However, continued research efforts will lead to further improvement of the model, and subsistence farming of today will become prestigious farming of the future.

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