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Research Paper

Economic sustainability of current cropping systems in the Indian Punjab: A case study

Sukhwinder Singh

Centre for Chronic Disease Control, Public Health Foundation of India.

Author Email: sukhrec@yahoo.com

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Abstract. Indian Punjab is a strategically important region in terms of India's current and future food security needs. However, stagnating productivity levels of major crops are denting the net farm profitability of farming enterprise in Punjab. This paper investigates the economic sustainability of current cropping systems in the Indian Punjab in terms of Relative Crop Yield Index (RCYI), Cost of Cultivation (CoC), Net Farm Profitability (NFP) and Annual Income from Farm Enterprise (AIFE) and their association with socioeconomic and agricultural factors. Both, the RCYI and CoC varied significantly across agro-climatic zones while the NFP and AIFE were statistically comparable across zones. Wheat-Basmati-Cotton-Sugarcane crop combination yielded the highest net farm profitability. The regression results suggest that an optimal use of fertiliser helped farmers yield a higher RCYI whereas higher crop diversity enabled farmers to cut the cost of cultivation. Farmers connected with agricultural extension networks could raise their net farm profitability significantly while an optimal use of pesticides maximised their annual income from farm enterprise. A typical farmer spent Rs 84,374 ($1,687) and earned Rs 12,055 ($241) from each hectare annually. An average farm of 4.8 ha could generate an annual income of Rs 55,887 ($1117) suggesting that a member of an average farmer household of five is surviving on Rs 46/day ($0.93). Therefore, an average farmer household of Punjab is living below "poverty line." Overall, most farm enterprises in the Indian Punjab are economically unsustainable due to higher cost of cultivation particularly using more fertilisers and pesticides and making heavy investment on farm machinery, and limited access to agricultural extension advisory.

Keywords: Agriculture, farm income, crop diversity, crop productivity, wheat-rice system.

INTRODUCTION

Indian Punjab is a strategically important region in terms of India's current and future food security needs (PSFC, 2013). However, the agricultural sector has been facing a range of socioeconomic challenges associated with stagnating productivity levels leading to low net farm profitability (Singh, 2016; Singh, 2013). Despite having relatively higher crop productivity levels than the respective national averages (GoP, 2012), farmers in Punjab are not able to sustain their farming enterprises economically due to increased cost of cultivation (Singh, 2012; Kalkat at al., 2006).

Wheat and rice are the major crops in Punjab covering 80% of cultivated area (GoP, 2012). The current policy framework for agriculture, especially the MSPAP (Minimum Support Price and Assured Purchase), unlicensed groundwater availability, and free-of-cost electricity to pump it out, has been encouraging farmers to prefer "rice-wheat-rice" rotation over other high value crops (Singh, 2013, 2016). This phenomenon has gradually led to a culture of mono-cropping lowering crop diversity in most regions of Punjab. For instance, the Crop Diversification Index (CDI) in Punjab has fallen from

0.75 in 1975-76 (Sidhu *et al*., 2010) to 0.42 in 2009-10 (Singh and Benbi, 2016: 327). Punjab government's crop diversification programs in the past (Johl, 1986) has had little success (Sarkar and Das, 2014; PSFC, 2013) because wheat and rice have always been relatively better priced and have lower productivity risks when compared with the alternative crops such as maize, cotton and sugarcane that have been suggested under various crop diversification plans to-date (Singh, 2016; Singh, 2013; Shergill, 2013; World Bank, 2003; Chand, 1999).

Various studies have investigated the profitability of current crop combinations in Punjab. Shergill (2007) and Singh *et al.* (2017) suggested that wheat-rice makes the most economically sustainable crop combination whereas Samra and Kataria (2014) argued that farmers cultivating vegetables could earn higher incomes than wheat-rice growers. Very few studies investigated the overall economic sustainability of farming enterprises in Punjab[a] using components such as relative crop yield[b], cost of cultivation, net farm profitability and annual farm income. Further, no study has attempted to associate these all components (e.g. crop productivity, cost of cultivation, net farm profitability) with socioeconomic and agricultural factors suggesting which of these factors can improve yield levels, reduce cost of cultivation, and fetch more farm income to raise the economic sustainability of Punjab's farming enterprises. Thus, this paper examines the economic sustainability of farm enterprises of Punjab presenting a quantitative analysis of Relative Crop Yield Index (RCYI), Cost of Cultivation (CoC), Net Farm Profitability (NFP) and Annual Income from Farm Enterprise (AIFE) to update the current knowledge on economic sustainability of farm enterprises in Punjab. It also investigates the association of socioeconomic and agricultural factors with RCYI, CoC, NFP and AIFE. The results from this paper could be applicable to Indo-Gangetic Plain of India and other similar cropping systems across the globe.

MATERIALS AND METHODS

Sampling

In 2010, a survey of 120 farmers was conducted across three districts, namely Gurdaspur, Barnala and Ferozepur, of the Indian Punjab (Singh and Benbi, 2016; Singh and Park, 2018c). A multistage cluster sampling technique was used to select districts, blocks, villages, and then farmers (S1). To start with, a Farming Intensity Index (FII) was calculated for each of the 20 districts of Punjab using the major indicators of agricultural sustainability in Punjab, e.g. per hectare agricultural production in value terms, condition of the underground water resources, state of soil health and Crop-Diversification Index (CDI). The data used to realise the FII components were largely calculated using secondary data resources. To calculate the FII, the values of each of the indicators for each of the 20 districts were normalised (X- x̄)/SD), and then all the realised values were added to obtain a composite score for each of the districts using the formula devised by Singh and Benbi (2016):

$$FII = \sum_{i=1}^{n} \frac{\mathrm{X} - \bar{\mathrm{x}}}{\mathrm{SD}}$$

Where
X = a set of actual values of the variable considered,
x̄ = Mean of X,
SD = Standard Deviation of X,
n = Number of variables.

For the current study, Gurdaspur, Barnala and Ferozepur, which represented the sub-mountainous, central and south-western agro-climatic zones of Punjab, respectively, were selected for a field survey. Maintaining consistency, three blocks, Gurdaspur, Sehna and Fazilika were selected in Gurdaspur, Barnala and Ferozepur districts, respectively. Then, owing to unavailability of secondary data on sustainability indicators at village level, the extension workers of the block concerned were consulted to identify two divergent (i.e., one relatively more and one relatively less intensively farmed) villages from each of the selected blocks.

After identifying the villages, 20 farmers, representing small, medium and large landholders belonging to all social classes, were selected from each of the six villages using a stratified sampling technique. A stratified sampling technique was purposefully used to include farmers belonging to all landholding categories[d] and social classes[e], so that the sampled farmers represent the entire village. A semi-structured interview schedule was used to collect a range of socioeconomic and agricultural data. For more details on the sampling

[a] To note, the crop production systems, in general, have a range of economic, environmental and social implications; however, this particular study focuses on the economic aspects of cropping systems in the Indian Punjab.

[b] In this study, crop productivity and yield will be used interchangeably.

[c] This paper is based on the same field survey as used in the papers Singh and Benbi (2016) and Singh and Park (2018).

[d] In India, small landholders are those who cultivate less than 2 ha whereas medium landholders cultivate between 2–10 ha and those who cultivate more than 10 ha are categorised as large landholders (GoP, 2012).

[e] Indian society has mainly four social classes, Scheduled Caste (SC), Scheduled Tribes (ST), Other backward Classes (OBC) and General (Munshi, 2019).

methodology, please refer to Singh and Benbi (2016) and Singh and Park (2018).

Calculation of CP, CoC, NFP, GI and AIFE

The Net Farm Profitability (NFP), Annual Income from Farm Enterprise (AIFE) were calculated for all the 120 farmers. The NFP was measured by using per hectare Crop Productivity (CP), Cost of Cultivation (CoC), and commodity prices. The actual commodity prices[f] (in Rs/100 kilogram) and the estimates of Cost of Production (A1) (in Rs/ha) for major crops[g] collected from farmers were used to calculate the Gross Income (GI; S2) and the Cost of Cultivation (C3)[h], respectively (S3). Per hectare NFP (in Rs) was realised from the GI and C3 figures (NFP = GI-C3) for major crops, and the AIFE for each farmer was calculated by multiplying the NFP with the size of operational landholding of that farmer (S4)[i].

Statistical models

The Statistical Package for Social Sciences (SPSS) was used to realise all the descriptive tables and analyse the data. For regressions, a general ANOVA model, which adjusts the predicted means of the dependent variable with respect to each independent variable for the effect of all the independent factors, was used. This model was preferred over other linear regression models as it quantifies the relationship between more than one independent or predictor variables and a dependent or criterion variable. This model goes a step beyond the multivariate regression model by allowing for linear transformations or linear combinations of multiple dependent variables. This extension gives the general linear model important advantages over the multiple and the so-called multivariate regression models. Tukey's honest significant difference (HSD) was used for post-hoc comparisons. To check multicollinearity, correlation values across all independent variables used in the regressions were examined using bivariate correlation and Chi-sqaure tests and no independent variable showed a siginificant association with each other.

Variables used in regressions

Four individual regressions were run to examine the associations between various socioeconomic and agricultural factors, as independent variables, and RCYI, CoC, NFP, and AIFE, as dependent variables. Various socioeconomic (e.g. landholding size, farmer age, education, investment on farm machinery, extension connectivity) and agricultural (e.g. fertiliser and pesticide input, cropping intensity, crop diversity, groundwater level, and soil health) factors were included in these regressions as independent variables. These factors were frequently used in the relevant literature and are largely considered as the factors that affect the economic sustainability of a farming enterprise directly.

RESULTS

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[f] Considering the recommendations of the Commission for Agricultural Costs and Prices (CACP), a body of Government of India, the Department of Agriculture and Co-operation declares Minimum Support Price (MSP) for 23 crops (including sugarcane). It gives farmers guaranteed prices and assured market and saves them from price fluctuations (Aayog, 2016).

[g] The major crop in the *Rabi* season was wheat occupying 83% of the cultivated area whereas, in the *Kharif* season, rice (paddy), basmati and cotton occupied 86% (combined) of the cultivated area. As the other crops, e.g. potato, sugarcane and green fodder, occupied only 14-17% of the net sown area, the CP, CoC, NFP and AIFE were calculated using four crops, e.g. wheat, rice, basmati and cotton. The Cost of Cultivation (A1) estimates provided by farmers include all production costs including irrigation costs. Although the cost of electricity to pull groundwater is zero for farmers in Punjab, the electricity supply to farm sector is erratic and irregular; farmers therefore use alternate private energy sources, e.g., diesel engine and tractor, to pull groundwater for irrigation. Moreover, there are some additional irrigation costs, such as maintenance costs of tube wells and cost of canal water, which were accounted against irrigation costs.

[h] As per the cost of cultivation estimates of the Commission for Agricultural Costs and Prices (CACP), the difference between the cost of production (A1) and cost of cultivation (C2) figures for wheat, rice and cotton was 44%, 45% and 21%, respectively (CACP, 2011). Thus, for this study, the cost estimates of A1 of wheat, rice and cotton collected from farmers were inflated by 144%, 145% and 121%, respectively, to get the C2 figures for wheat, rice and cotton. As the CACP does not calculate the cost of cultivation for basmati, the A1 estimates of basmati collected from farmers were inflated by 136% (the average of 144%, 145%, and 121%) to get the C2 figures for basmati. The C2 figures for wheat, rice, basmati and cotton were further inflated by 10% to get the final cost of cultivation (C3) referring to the CACP formula used to calculate the C3. To note, the data related to AI and C2 used here pertains to 2007-08, the latest published data by the CACP in 2011. The average per hectare cost of cultivation (C3) is a weighted average of C3 of wheat, rice, basmati and cotton, the major *Rabi* and *Kharif* crops of Punjab occupying 83-86% of the net sown area.

[i] AIFE is based on the average NFP/ha of the major crops, e.g. wheat, rice, basmati and cotton, grown on 83-86% of the cultivated area. Other crops grown on the remaining 14-17% of cultivated area were excluded from these calculations.

Table 1. Crop Productivity (Yield) of major crops across all three agro-climatic zones of Punjab for 2010-11.

Agro-climatic zone	Wheat (N=120)			Rice (N=73)			Basmati (N=32)			Cotton (N=38)		
	Yield (t/ha)	SD	CV	Yield (t/ha)	SD	CV	Yield (t/ha)	SD	CV	Yield (t/ha)	SD	CV
Sub-mountainous zone (Gurdaspur)	3.6	0.74	21	5.3	0.91	17	3.8	0.52	14			
Central zone (Barnala)	4.5	0.48	11	8.2	0.62	8				2.6	0.62	24
South-western zone (Ferozepur)	3.9	0.60	15				4.9	0.68	14	2.3	0.39	17
Overall	4.0	0.71	18	6.8	1.66	24	4.8	0.73	15	2.4	0.54	23

Notes: SD: Standard Deviation; CV: Coefficient of Variance. Source: Survey data.

Farmer profile and cropping patterns

A typical sampled farmer was cultivating 4.8 ha[j] (*Min* = 0.4 ha, *Max* = 13.6 ha, *SD* = 3.4), this mean was almost the same over the three zones: sub-mountainous zone with 4.9 ha followed by south-western with 4.7 ha and central zone with 4.6 ha. Most farmers went to school up to 12th Standard; 11% were graduates. All farmers across the three agro-climatic zones grew at least two crops in a given year, which raised their average cropping intensity to 200% with significant intra-zone variations [$X^2(4, 120) = 16.1$ $p < .01$] while farmers in the central (Barnala) and south-western (Ferozepur) zone had a combined average cropping intensity of 202%. Wheat and potato were the main *Rabi* season (November-April) crops while rice, basmati and cotton were cultivated during the *Kharif* season (May-November) and sugarcane was an annual crop. About 83% and 73% of the net sown area was under wheat and rice in the *Rabi* and *Kharif* seasons, respectively. In relation to the diversity of cropping systems, the overall crop diversity across all three zones was 0.61. However, cropping patterns in the *Kharif* season were slightly more diverse.

Crop yield/productivity

The average per hectare crop productivity (yield) of wheat, rice[k], basmati and cotton among 120 farmers across all three zones was 4, 6.8, 4.8 and 2.4 t ha^{-1}, respectively (Table 1). Comparing the zone-wise crop productivity levels, farmers in the central zone had the highest yield of wheat, rice and cotton while basmati yield was higher in the south-western zone than in the sub-mountainous zone. To note, wheat was cultivated across all zones while rice was sown in the sub-mountainous (Gurdaspur) and the central (Barnala) zones only. Basmati was one of the major Kharif crops in the sub-mountainous and south-western (Ferozepur) zones. Similarly, cotton was cultivated in the central and south-western zones only. Farmers in the central zone had the highest productivity levels of wheat and rice with the lowest intra-zone variations. Farmers in the sub-mountainous zone could not match the overall averages while those, who were in the south-western zone, had crop yield levels close to the respective overall averages. A one-way AVOVA indicated that wheat, rice and basmati yield levels varied significantly with respect to agro-climatic zones [wheat: $F(2, 117) = 21.836$, $p < .01$; rice: $F(1, 71) = 254.407$, $p < .01$; and basmati: $F(1, 30) = 7.022$, $p < .05$] whereas for cotton, it was statistically similar. The Tukey's HSD post-hoc comparisons revealed that wheat yield was significantly higher in the central zone (Mean difference = 0.9 t ha-1, SE = .137, p < .001) than in the sub-mountainous as well as in the south-western zone (Mean difference = 0.6 t ha^{-1}, SE = .137, p < .001).

Further, a Relative Crop Yield Index (RCYI- a relative efficiency of each farmer against the overall average efficiency)[l] for each farmer was calculated by normalising the average yield of wheat, rice, basmati and cotton against the overall averages and factoring in the proportionate land area under each crop (S5). It ranged between 0.59 and 1.32 (*CV* = 17.60%) for all 120 farmers across three agro-climatic zones. The RCYI varied significantly with respect to agro-climatic zones, $F(2, 92) = 24.631$, $p < .01$, and fertilisation, $F(2, 92) = 4.356$, $p < .05$, only (Table 2).

Farmers in the central zone (1.17) had the highest RCYI followed by those in the south-western (0.96) and in the sub-mountainous zone (0.79) (Figure 1). The post-hoc comparisons indicate that the average RCYI was

[j] The average landholding size of 4.8 ha was calculated by excluding six outliers of 16, 17.2, 18, 28, 30 and 36 ha. With these outliers, the average landholding was 5.7 ha.

[k] Here, rice refers to paddy crop, an ordinary variety of rice, which is procured by the Indian government on a prefixed MSP. On the other hand, Basmati, a premium variety of long-grain Indian rice with a delicate fragrance, does not have MSP support (PSFC, 2013).

[l] Relative Crop Yield Index (RCYI) is an overall crop productivity that measures the relative efficiency of each farmer against the overall average efficiency of the entire sample. It was calculated by normalizing the average yield of wheat, rice, basmati and cotton against the overall averages for each crop and factoring in the proportionate land area under each crop (S5).

Table 2. A general ANOVA model showing the level of variation in the Relative Crop Yield Index (RCYI) with respect to various socioeconomic and agricultural factors.

Tests of between-subjects effects					
Dependent Variable: Relative Crop Yield Index (RCYI)					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	2.476[a]	27	.092	7.409	.000
Intercept	12.287	1	12.287	992.708	.000
Agro-climatic region	**.610**	**2**	**.305**	**24.631**	**.000**
Landholding size	.003	2	.001	.116	.891
Farmer age	.014	2	.007	.555	.576
Farmer education	.017	2	.009	.694	.502
Farm machinery/ha	.059	3	.020	1.590	.197
Fertiliser use/ha	**.108**	**2**	**.054**	**4.356**	**.016**
Pesticide use/ha	.022	3	.007	.587	.625
Cropping intensity	.051	2	.026	2.077	.131
Crop diversity	.014	2	.007	.547	.581
Groundwater Level	.024	3	.008	.649	.585
Soil Health Index (SHI) #	.003	2	.001	.105	.900
Connectivity to Extension	.001	1	.001	.045	.833
Error	1.139	92	.012		
Total	121.271	120			
Corrected Total	3.615	119			
a. R Squared=.685 (Adjusted R Squared= 593)					

Notes: # Soil Health Index is a composite index calculated by testing the soil samples collected from farmers. In Table 3 and 4 too, it is has the same meaning. *Source*: Model results

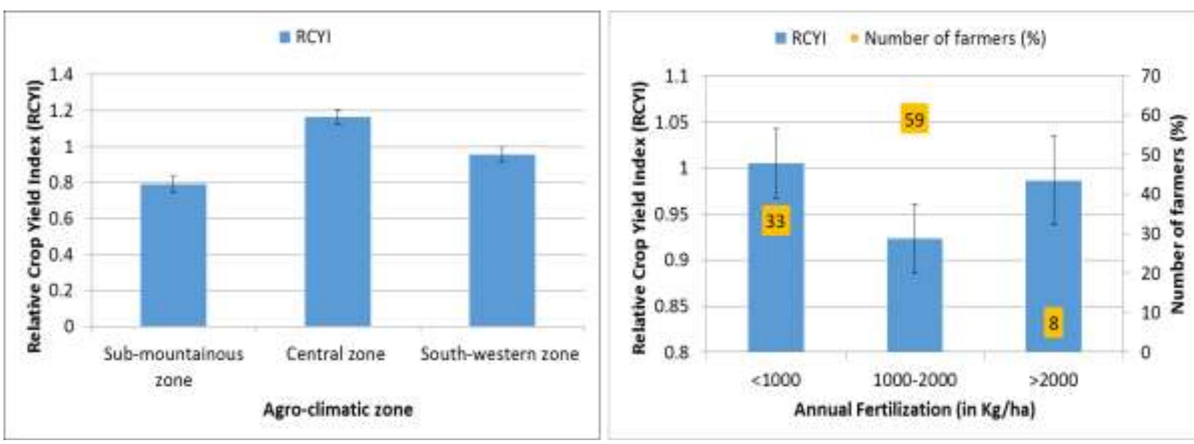

Figure 1. The Relative Crop Yield Index (RCYI) with respect to agro-climatic zones (1a) and annual fertilisation (1b) + error bars. Source: Survey data.

significantly higher in the central zone (*Mean difference* = 0.33, *SE* = .025, *p* < .001) than in the sub-mountainous and south-western zone (*Mean difference* = 0.19, *SE* = .026, *p* < .001). Further, it was also significantly higher in the south-western zone (*Mean difference* = 0.13, *SE* = .025 *p* < .001) than in the sub-mountainous zone. In relation to fertilisation (Figure 1), farmers who used fertilisers up to 1000 kg per ha, could manage a higher RCYI as compared to those who used higher dozes. The post-hoc comparisons indicate that farmers using fertilisers up to 1,000 kg/ha had a higher RCYI (Mean difference = .07, SE = .022, p < .01) than those who

Table 3. A general ANOVA model showing the level of variation in average annual Cost of Cultivation (in Rs/ha) with respect to various socioeconomic and agricultural factors.

Tests of between-subjects effects					
Dependent Variable: Cost of Cultivation (in Rs/ha)					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	111665926663.736[a]	29	3850549195.301	9.811	.000
Intercept	61940202641.614	1	61940202641.614	157.815	.000
Region	**7263653402.963**	**2**	**3631826701.482**	**9.253**	**.000**
Landholding size	1052388876.980	2	526194438.490	1.341	.267
Farmers' age	41813093.086	2	20906546.543	.053	.948
Farmers' education	11426180.306	2	5713090.153	.015	.986
Investment on farm machinery/ha	437025967.501	3	145675322.500	.371	.774
Annual fertilizer input (in kg/ha)	65232291.388	2	32616145.694	.083	.920
Annual pesticide input (in Rs/ha)	2842265732.760	3	947421910.920	2.414	.072
Cropping intensity	1008583757.714	2	504291878.857	1.285	.282
Crop diversity	**7172907916.459**	**2**	**3586453958.230**	**9.138**	**.000**
Crop combinations	351166107.057	2	175583053.528	.447	.641
Groundwater Level	1639447693.196	3	546482564.399	1.392	.250
Soil Health Index (SHI)	538833077.419	2	269416538.710	.686	.506
Connectivity to Extension	1414645384.314	1	1414645384.314	3.604	.061
Error	35323686858.265	90	392485409.536		
Total	1001266238642.000	120			
Corrected Total	146989613522.000	119			
a. R Squared = .760 (Adjusted R Squared = .682)					

Source: Model results

applied fertilisation of 1,000 to 2,000 kg/ha and also than those who went beyond 2,000 kg/ha (Mean difference = .22, SE = .041, p < .001).

Cost of cultivation

Each farmer, on average, spent Rs 84,374 ($1,687)[m], ranging between Rs 24,235 ($485) and Rs 1, 96,053 ($3,921), annually on each hectare of land cultivating two crops in a given year (2009-10) (S3). Subsequently, the average annual CoC on all crops was Rs 507,366 ($10,147) which widely fluctuated between Rs 18,436 ($369) and Rs 5,489,484 ($109,790). Crop-wise, it was the highest for cotton (Rs 68,604/ha = $1,372) followed by basmati (Rs 62,071/ha = $1,241), rice (Rs 53,362/ha = $1,067) and wheat (Rs 39,060/ha = $781). A one-way AVOVA indicated that the average per hectare CoC of wheat, $F(2, 117) = 45.394$, $p < .001$, rice, $F(1, 71) = 143.465$, $p < .001$, and basmati, $F(1, 30) = 23.287$, $p < .001$, varied significantly with respect to agro-climatic zones whereas, in the case of cotton, it was statistically similar. The average annual per hectare CoC varied significantly with respect to agro-climatic zones [$F(2, 90) = 9.253$, $p < .01$], and crop diversity [$F(2, 90) = 9.138$, $p < .01$] only whereas with respect to all other factors listed in Table 3, the numerical differences were insignificant.

Figure 2 shows that a typical farmer in the sub-mountainous zone spent Rs 50,236 ($1,005) on cultivating each hectare of land. It was significantly lower than what farmers in the central and the south-western zone (Rs 80,389 = $1,608) spent. Further, the CoC varied significantly between the central and south-western zones as well. However, the RCYI corresponded with the CoC although disproportionately (Figure 2). For instance, farmers in the central and south-western zones obtained only 54 and 17% higher crop productivities although they spent 87 and 60%, respectively, more per ha compared to farmers in the sub-mountainous zone. Notably, the RCYI varied significantly across zones (Table 2). Further, crop diversity and the CoC had an inverse relationship (Figure 2) suggesting farmers having lower crop diversity were spending more on cultivation. However, farmers with average crop diversity (0.60 to 0.70) had the highest RCYI whereas those with the lowest (<0.60) and the highest diversity (>0.70) had

[m]The average conversion rate for $1 to INR (Rs-Indian Rupee) was Rs 50 in 2010. This will remain constant throughout the paper.

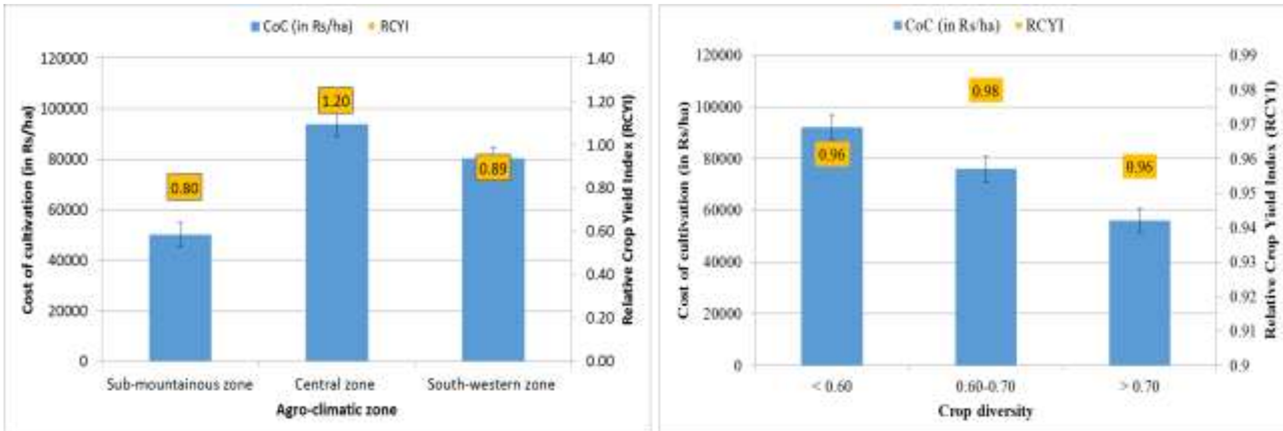

Figure 2. Cost of cultivation (in Rs/ha) with respect to agro-climatic zone and the level of crop diversity + error bars. Source: Survey data.

similar RCYI.

Net farm profitability

A typical farmer earned Rs 10,545 ($211) ranging between a loss of Rs -79,027 (-$1,580) and a profit of Rs 73,910 ($1.478) annually cultivating one hectare of land (S4). Zone-wise, it was the highest (Rs 18,970 ($379) in the sub-mountainous zone followed by the south-western zone (Rs 7,395 ($148) and the central zone (Rs 4,569 ($91). Crop-wise, the two highest profit generating crops were basmati (Rs 25,043/ha = $502) and rice (Rs 13,045/ha = $261) whereas wheat (Rs 1,612/ha = $32) had very low per hectare net profitability. Cotton growers faced a loss of Rs 759/ha ($15) on each hectare. The average NFP (Table 4) varied with respect to crop combinations [$F(2, 90) = 6.901$, $p < .01$], and extension connectivity [$F(1, 90) = 5.851$, $p < .05$].

Although there were total ten crop combinations[n], the three largest growing crop-combinations were Wheat-Rice-Cotton-Sugarcane-Potato (WRCSP), Wheat-Basmati-Cotton-Sugarcane (WBCS), and Wheat-Cotton (WC). The WBCS combination generated the highest per hectare net profit (Rs 27,613 = $552) which could be due to a relatively higher RCYI among the growers of this crop-mix (Figure 3). The other high profit generating crop combination was the WRCSP combination (Rs 7,166 = $143) although the RCYI was noticeably lower among the growers of this crop-mix. The WC combination brought an average loss of Rs 3,551 ($71) to its growers. Furthermore, considering the individual crop-wise profits, basmati fetched much higher returns than wheat, rice and cotton. Further, farmers connected to extension could generate about four times higher NFP per ha (Rs 16,469 = $329) than those who did not have such extension connectivity (Rs 4,350 = $87) although the reach of extension was limited to only 26% of the total farmers surveyed. Probably, farmers using extension advisory were able to generate relatively higher farm incomes than their counterparts by improving crop yields and/or cutting their cost of cultivation making use of modern farm technologies. However, the regression results of this study (Tables 2 and 3) do not show this explicitly. To note, agricultural extension system in the Indian Punjab has weaken overtime due to financial crunch and inadequate staff both in the Department of Agriculture and the Extension Directorate at the Punjab Agricultural University, Ludhiana (Singh, 2010; Khanna 2011). Additionally, a limited number of NGOs and the almost non-existence of farmer-run Civil Society Organizations have also dented agricultural extension in the state (NSSO, 2005).

Annual income from farm enterprise

An average farm of 4.8 hectare could generate an annual income (AIFE) of Rs 50,201 ($1,004) with the highest in the sub-mountainous zone (Rs 91,057 = $1821) followed by the south-western zone (Rs 34,757 = $695) and the central zone (Rs 21,475 ($430) (S4). More than one-fifth of farmers, of which 90% were small and medium holders, had to bear a loss of Rs 17,267 ($345) ranging between Rs 379 ($8) and Rs 79,027 ($1,580) on each hectare of land whereas the annual loss from these farm enterprises was Rs 75, 819 ($1,516) with a range of Rs 987 ($20) to Rs 3,83,851 ($7,677).

The average AIFE varied significantly in the case of pesticide input [$F(3, 90) = 2.990$, $p < .05$] only (Table 5).

[n] Punjab's agro-climatic conditions allow farmers to cultivate their land at least twice a year i.e. *Rabi* and *Kharif* season. Thus; here a crop combination means a set of *Rabi* and *Kharif* crops grown by a farmer in a given year during both the seasons.

Table 4. A general ANOVA model showing the level of variation in the average Net Farm Profitability (in Rs/ha) with respect to various socioeconomic and agricultural factors.

Tests of between-subjects effects					
Dependent Variable: Net Farm Profitability (in Rs/ha)					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	32033673030.3366[a]	29	1104609414.839	2.522	.000
Intercept	1199539807.620	1	1199539807.620	2.739	.101
Region	845684814.460	2	422842407.230	.966	.385
Landholding size	1928940861.514	2	964470430.757	2.202	.116
Farmers' age	247866007.363	2	123933003.682	.283	.754
Farmers' education	61247721.585	2	30623860.792	.070	.933
Investment on farm machinery/ha	349762782.549	3	116587594.183	.266	.850
Annual fertilizer input/ha	1079068599.381	2	539534299.690	1.232	.297
Annual pesticide input (in Rs/ha)	902620731.232	3	300873577.077	.687	.562
Cropping intensity	5521238.494	2	2760619.247	.006	.994
Crop diversity	180001693.671	2	90000846.835	.206	.815
Crop combinations	**6044361847.810**	**2**	**3022180923.905**	**6.901**	**.002**
Groundwater Level	1155101960.325	3	385033986.775	.879	.455
Soil Health Index (SHI)	783005670.957	2	391502835.478	.894	.413
Connectivity to Extension	**2562315382.846**	**1**	**2562315382.846**	**5.851**	**.018**
Error	39413466741.530	90	437927408.239		
Total	86693105932.000	120			
Corrected Total	71447139771.867	119			
a. R Squared = .448 (Adjusted R Squared = .227)					

Source: Model results.

Farmers applying pesticides above Rs 50,000/ha ($1,000/ha) had to face losses up to Rs 159,073 ($3,181) although such farmers accounted for only 8%. In contrast, those who opted for not using any pesticide or kept the pesticide usage below Rs 10,000/ha ($200/ha) ended up earning higher annual incomes from their farm enterprise. However, farmers spending Rs 10,000-50,000/ha ($200-$1,000/ha), who accounted for about half of the farmer population, on pesticides could earn Rs 79,622 ($1,592) from their farm enterprises despite lower crop productivity levels. However, the RCYI and pesticide use had no significant association (Table 2).

DISCUSSION

Economic sustainability of a farm enterprise depends mainly on crop productivity, cost of cultivation, and commodity prices[o]. The overall crop productivity (i.e. RCYI) was significantly lower in the sub-mountainous zone (Gurdaspur) than in the central (Barnala) and the south-western (Ferozepur) zone (Table 2 and Figure 1). This variation could be because of three main reasons: first, some farmers could not cultivate their land potentials fully due to water logging conditions particularly in Nushehra Bahadur, one of two villages surveyed in the sub-mountainous zone. Second, canal irrigation was not available to any farm in the sub-mountainous zone whereas in the central and south-western zones, 42 and 100% of cultivable area was irrigated with canal water, respectively (S6). Third, the cropping intensity, which had a positive significant correlation with RCYI (r = .312, n = 120, p < .01), was significantly lower in the sub-mountainous zone than in the other two zones[p]. Besides agro-climatic conditions, an optimal use of fertilisers in the sub-mountainous zone helped farmers yield a higher RCYI. Since the association between total fertilisation

[o] The commodity prices of major crops were more or less similar for all the farmers across all three zones as wheat and rice are largely procured by the government agencies at pre-fixed price (i.e. Minimum Support Price). However, cotton and basmati prices, they, being sold in the open market, could vary slightly. Thus, here in this paper, the farm profitability depended, by and large, on crop productivity and cost of cultivation.

[p]The average cropping intensity was 196% in the sub-mountainous zone comparing 203% and 200% in the central and south-western zone, respectively.

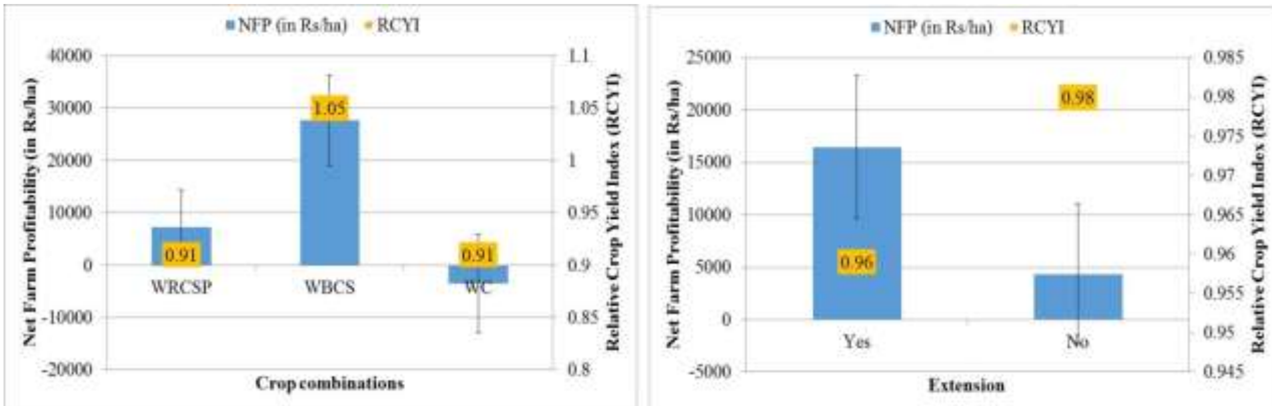

Figure 3. The average per hectare Net Farm Profitability (NFP) and the Relative Crop Yield Index (RCYI) with respect to various crop combinations farmers grew and farmer connectivity to extension + error bars. *Notes*: WRCSP = Wheat-Rice-Cotton-Sugarcane-Potato; WBCS = Wheat-Basmati-Cotton-Sugarcane; WC = Wheat-Cotton. Source: Survey data

Table 5. Average Annual Income from Farm Enterprise (AIFE) and the Relative Crop Yield Index (RCYI) with respect to varying annual pesticide input.

Annual pesticide input (in Rs/ha)	AIFE (Rs)	RCYI	Number of farmers (%)
No pesticides	114,340	1.01	25
Below 10,000	156,066	0.95	22
10,000-50,000	79, 622	0.96	46
Above 50,000	-159,073	0.95	8

Source: Survey data

Table 6. Annual fertilizer input, pesticide usage and cropping intensity across agro-climatic zones.

Agro-climatic Zone	Fertilizer input (in kg/ha)	Pesticide input (in Rs/ha)	Cropping intensity (%)
Sub-mountainous zone (Gurdaspur)	1,038	918	196
Central zone (Barnala)	1,502	26,740	203
South-western zone (Ferozepur)	1,248	24,244	200
Overall	**1,262**	**22,503**	**200**
The level of significance indicated by a one-way ANOVA	$F(2, 117) = 8.744$, $p < .01$	$F(2, 89) = 6.585$, $p < .01$	$F(2, 117) = 5.420$, $p < .01$

Source: Survey data

and productivity levels is unclear (Figure 1), it cannot be established that lower fertilisation can always lead to higher productivity levels. To note, farmers in the Indian Punjab use much higher doses of fertilisers and pesticides when compared to farmers in the other Indian states to maintain the crop yield levels. For instance, per hectare use of fertilizer and pesticide in Punjab was 192.5 kg and 923 gm respectively which is the highest in India and almost double the national average (MoA, 2009; Tiwana *et al*., 2007). Although this study did not investigate the associations between the use of different fertiliser types and crop productivities, the type of fertiliser, ratio of Nitrogen (N), Phosphorus (P) and Potassium (K), and time of their application are equally considerable factors affecting crop yield (NAAS, 2005; Johri and Yadav, 2006; Gulati and Banerjee, 2015). Further, the average fertiliser and pesticide inputs in this study seem to be very high (Tables 5 and 6). Various reports (GoP, 2012; Fertilizer Association of India, 2010; MoA, 2009) and studies (Chand and Pavithra, 2015; Tiwana *et al.,* 2007) endorse these findings and reported that Punjab is one of the Indian states where fertilizer and pesticide input is much higher as compared to other Indian states, and NPK ratio is imbalanced generally tilted towards to high doses of Nitrogen.

The Cost of Cultivation (CoC) of wheat and rice was lower than that of cotton and basmati (S7). For instance, the cotton and basmati growers, respectively, spent about 28 and 16% more on farm inputs (CoC) than what the rice growers did. Endorsing these results, a study on the current agricultural practices in Punjab (Kaur *et al*., 2010) revealed that wheat and rice were the crops with the highest variable cost as compared to respective alternative crops in *Rabi* and *Kharif* seasons, respectively. Moreover, the official State level cost estimates were within the 95% of CI (Confidence Interval) for the respective sample means of all crops except wheat. Further, Wheat-Cotton was the most expensive crop combination while the growers of Wheat-Rice combination spent 9 and 16% (per ha) less than those who opted for Wheat-Basmati and Wheat-Cotton combinations, respectively. These estimates were, by and large, close to official State level figures (S7).

A typical farmer spent Rs 84,374 ($1,687) annually on cultivating each hectare of land. Farmers in the central and south-western zone spent 86 and 60% annually more on cultivation than those in the sub-mountainous zone, respectively. In the central zone, it could be attributed to significantly higher fertilizer and pesticide input and cropping intensity compared with the sub-mountainous zone (Table 6). Relatively, farmers in the central zone used 19% more fertilizers and pesticides than the respective overall averages. In contrast, in the sub-mountainous zone, farmers used 82% of the overall fertilizer usage and just 4% of overall pesticide usage, and had a significantly lower cropping intensity level. However, the corresponding figures in the south-western zone were close to the respective overall averages. Additionally, crop diversity had an inverse relationship with CoC suggesting farmers experimenting with a large set of crops could reduce their per hectare cost of cultivation compared to those who kept their cropping patterns limited to two crops only e.g. wheat and rice. For instance, farmers who grew only two crops spent 9 and 22% more on cultivating each hectare than those who grew four and five crops, respectively. Therefore, cropping patterns with higher diversity could help farmers reduce their annual per hectare cost of cultivation and in turn, enhance the economic sustainability of their farm enterprises because the cost of cultivation and net farm profitability were significantly ($r = .727$, $n = 120$, $p = .01$) correlated to each other. Further, while endorsing these findings, a district level study in Odisha (Basantaraya and Nancharaiah, 2017) suggested that farms having more diversified cropping patterns had higher gross and net farm incomes than those with least and moderate diversified cropping systems.

Comparing the net profitability of major crops, basmati was the highest profit generating *Kharif* crop followed by rice, wheat and cotton. These results are endorsed by a couple of recent studies on Punjab agriculture (Singh *et al*., 2017; Raju *et al*., 2015) where basmati fetched the highest gross returns and net returns using market prices, economic prices, and natural resource valuation. On the other hand, cotton generated the lowest per hectare net profit which could be attributed to its higher cost of cultivation (S7). Additionally, cotton cultivation is prone to the highest level of productivity and marketing risks when compared to other Kharif crops (Chand, 1999) which could dent its net profitability.

From an economic sustainability angle, a typical farm enterprise could generate an annual income (i.e. AIFE) of Rs 50,201 ($1,004). To note, it does not include income from allied activities e.g. dairy, fishery. As per a recent survey by NSSO (2014), income from crop production in Punjab during 2012-13 contributed up to 60% to total income of a farmer household. Thus, adding an assumptive figure of 40% of total income of a farm household for an income from other allied farming activities like dairy, poultry etc., to Rs 50,201 ($1,004), an average farmer household could have earned Rs 83,668 ($1,673) from all sources. Analysing this figure in the context of farmer livelihoods in the Indian Punjab, an average monthly income of a farmer household comes to be Rs 6,972 ($139). That means an average farmer household of five members in Punjab lived on Rs 1,395 ($28) in a month. Considering the per-capita income, a member of a farming family of Punjab had Rs 46 ($0.93) to spend in a day. If those who live on $1.25 a day are poor as per IFAD (2011) estimation, an average farm household of '*so-called'* agriculturally advanced state like Punjab is in deep poverty. Even the Indian government's estimates on poverty line estimates for 2011-12 (Planning Commission, 2013) revealed that a person living in the rural Punjab is to be considered below poverty line if he or she earns less than Rs 1,054 ($21) per month. Therefore, the economic sustainability of current cropping systems in Punjab is debatable.

CONCLUSIONS

Although Indian Punjab is an important region from India's food security standpoint, stagnating productivity levels of major crops have dented the economic sustainability of farming enterprises in Punjab. This paper investigates the economic sustainability of current cropping systems in the Indian Punjab in terms of Relative Crop Yield Index (RCYI), Cost of Cultivation (CoC), Net Farm Profitability (NFP) and Annual Income from Farm Enterprise (AIFE) and their associations with various socioeconomic and agricultural factors. Both, the RCYI and CoC varied significantly across agro-climatic zones while the NFP and AIFE were statistically comparable across zones. Wheat-Basmati-Cotton-Sugarcane crop combination yielded the highest net farm profitability. The regression results suggest that an optimal use of fertiliser helped farmers yield a higher RCYI whereas higher crop diversity enabled farmers to cut the cost of cultivation. Farmers connected with agricultural extension networks could raise their net farm profitability while an optimal use of pesticides maximised their annual income from farm enterprise. An average farmer spent Rs 84,374 ($1,687) and earned Rs 12,055 ($241) from each hectare annually. An average farm of 4.8 ha could generate an annual income of Rs 55, 887 ($1117) suggesting that a member of an average farmer household of five is surviving on Rs 46/day ($0.93). Considering the state and Indian governments' rural poverty yardsticks, an average farmer household of Punjab are living below "poverty line." Overall, most farm enterprises in the Indian Punjab are economically unsustainable due to higher cost of cultivation particularly using more fertilisers and pesticides and making heavy investment on farm machinery, and limited access to agricultural extension advisory.

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