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Research Paper

# Quantification of Linkages within the Prevailing Integrated Farming Systems of Punjab

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## ABSTRACT

With the emerging problems owing to mono-cropping of paddy-wheat, diversification and integrated farming systems (IFS) is the need of the hour in Punjab, government of state is making efforts through earmarking budgetary allowances and several remunerative schemes to encourage farmers for its adoption. Hence, this study was taken upto understand the dynamics and the level of integration between the sub-components of widely adopted IFS models of Punjab. More than 80 percent of the farmers adopt the crop + dairy model in the study area therefore this prevalent model was studied as IFS-I model along with its variants of crop + dairy + mushroom (IFS-II) and crop + dairy + beekeeping (IFS-III) models. Leontief's input-output model (1966) were used to quantify the inter component relationship by considering crop, dairy, mushroom, beekeeping, household, and the market as separate sectors of the farming economy. It was concluded that component enterprises, depended upon each other for input supplies and disposal of output. Forward linkage from crop to dairy enterprise was stronger than backward linkage in all the IFS models and the dairy enterprise was self-sufficient in providing inputs for itself from within the system.

## HIGHLIGHTS

- Forward and backward linkages exist between the component enterprises in an IFS model.
- Mushroom and dairy enterprises had better co-dependence within the IFS models.

**Keywords:** Farm enterprise, input-output analysis, farming system

The very concept of an integrated farming system (IFS) conveys an arrangement wherein a farmer has several interdependent enterprises at his disposal, which are interlinked to a certain degree with one or the other. This approach allows the optimal utilization of on-farm resources and curtails the explicit cost by changing it into implicit costs. There is no absolute distinction between the integrated farming system and the commercial farming system, but they differ in the degree of integration of resources within the system (Tipraqsa *et al*. 2007). In India, there is an age-old practice of using farmyard manure as an essential fertilizer for land preparation, and grains and straw have been commonly used for feeding the animals. Therefore, the main/by-product of one enterprise is commonly used as an input in the other component of the farming system leading to co-dependency on each other. There exists a state of balance and strong linkage among the different enterprises which leads to saving on the part of the farmer as the resources available on the field are utilized to their maximum potential.

Nation-wide studies have been conducted for identifying the linkage between component enterprises of the farming systems and it has been established that there exists heavy interdependence upon the components of dairy-based, cereal-based, vegetable-based, sugarcane-based, and fruit-based

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farming systems (Sharma *et al*. 2001; Shalander, 1998; Saha, 2003; Singh *et al.* 2009). To quantify the linkages, several methods of Norman (1979), static input-output model, and Leontief's input-output model (1966) were employed in the studies of Arya and Kalla (1992), Shalander (1998), Sharma *et al.* (2001) and Sangpuii (2017).

Apart from forward and backward linkages, efficient nutrient recycling is also an integral part of integrated farming system models. Several studies have stated that recycling of crop residues is a pre-requisite in the crop-based farming system as 80-90 per cent of the micronutrients remain in the biomass wherein crop residues are utilized as animal feed, while by-products of livestock production, in turn, enhance agricultural productivity by improving soil fertility and providing nutrients, helping the multiplication of earthworms also known as farmers' friend (Shalander, 1998; Kumar *et al*. 2011; Kumar *et al*. 2018).

## MATERIALS AND METHODS

The present study was conducted in the Punjab state of India for examining the prevalent integrated farming systems (IFS) adopted by the farmers. Three IFS models were identified depending upon the widespread adoption of crop + dairy integration i.e., crop + dairy (IFS-I), crop + dairy + mushroom (IFS-II), and crop + dairy + beekeeping (IFS-III). A total of 100 IFS adoptee farmers were interviewed for 2019-20 and the primary was analysed for furnishing the linkages among them, out of which 40 respondents were selected for the IFS-I model and 30 respondents each were interviewed from IFS-II and IFS-III models, respectively. Co-dependence within the component enterprises was studied to reveal that both forward and backward linkage existed between them but to a varying degree.

To identify and quantify the existing linkage within the production unit, farming enterprises were considered as separate sectors viz., crops, dairy, mushroom, beekeeping, labour, market, and autonomous entity (farming household). It was assumed that each enterprise required a combination of inputs from itself and other enterprises to produce a unit of output, which was in turn sold to other enterprises to meet their input requirements. For example, the household sector sells out its output (services) to other sectors and in return receives consumer goods (household inputs) from other sectors. Marketed output from the farm was considered to be equal to marketable surplus as no distress sale was observed during the investigation. Similarly, any off-farm input was considered as purchased or hired-in from the market sector. All the estimations for quantifying the linkage between sectors were based on field data. The transaction matrix accounted for all the monetary transfer of inputs and outputs among the various sectors of the farm economy, which was studied both horizontally and vertically. Horizontally, each row represents the total production of one sector offered/sold to other sectors of the economy during a given period. Vertically, each column displays the total inputs used/purchased by the individual sector from adjoining sectors of the economy in the given time.

Let the $n$ number of sectors be denoted by $S_1$, $S_2$, ..., $S_n$. Let the number of units produced by sector $S_i$ necessary to produce one unit by sector $S_j$ be denoted by $a_{ij}$, and the number of externally demanded units of sector $S_i$ be denoted by $b_i$. Let $x_1$, $x_2$, ..., $x_n$ be the total output of sectors $S_1$, $S_2$, ..., $S_n$, respectively. Then,

$$S_1 = a_{11}\,x_1 + a_{12}\,x_1 + \ldots + a_{1n}\,x_1 + b_1 \qquad \ldots(1)$$

$$S_2 = a_{21}\,x_2 + a_{22}\,x_2 + \ldots + a_{2n}\,x_2 + b_2$$

$$S_n = a_{n1}\,x_1 + a_{n2}\,x_n + \ldots + a_{nn}\,x_n + b_n$$

An input-output model may be denoted by the following equation:

$$S_i = \Sigma S_{ij} + H_i \qquad \ldots(2)$$

where,

$I$ = 1,2, 3,…, $m$

$j$ = 1,2, 3,…, $n$

$S_i$ = the output of any intermediate sector

$S_{ij}$ = components flow from sector to sector and,

$H_i$ = final output for household consumption and market.

Equation (2) may be re-written as:

$$S_i - \Sigma S_{ij} = H_i \qquad \ldots(3)$$

The equation (2) can also be demonstrated as a transaction matrix, representing the value of output flows from the producing sectors to the consuming sectors of the farm unit. Information from the transaction matrix was useful for computing the relationship between inputs furnished to the individual sector by itself and the adjoining sectors The resultant relationship can also be expressed in terms of production coefficients ($a_{ij}$) as follows:

$$a_{ij} = \frac{S_{ij}}{S_j} \quad \ldots(4)$$

Equation (4) may also be expressed as:

$$S_{ij} = a_{ij} S_j \quad \ldots(5)$$

where, $S_j$ = total output of sector '*j*'

In the equation (4) and (5), '$a_{ij}$' refers to the worth of a rupee of the output of '$i^{th}$' sector required by sector '*j*' per unit value of the output of sector '*j*'. Upon substituting the values of '$S_{ij}$' of equation (5) in equation (3), the resultant equation was:

$$S_i - \Sigma a_{ij} S_j = H_i \quad \ldots(6)$$

Equation (6) represents the functional relationship between the autonomous sectors and net output ($S_i$) and the relationship between intermediate sectors ($a_{ij}$) in the farm economy. The monetary value of inputs and outputs of all the enterprises was taken into account for establishing the linkages as the output from sectors differed in terms of quantity.

### Estimation of input-output linkage

The crop sector provides feed and fodder for the livestock sector and in return, the latter provides manure for the crops, similarly, wheat straws act as compost for mushrooms and the output is consumed by the households. In the present study, a 20 percent increase in the yield from oilseed crops was considered for calculating the contribution of bees within the IFS-III model as empirical evidence points towards enhancement of yield for rapeseed & mustard, and sunflower crops due to beekeeping within the range of 12.8 to 48.2 percent (Duraimurugan and Reddy, 2018). Several worldwide research has also concluded that honeybees and crops support each through respective transactions of cross-pollination facilities and nectar. However, unwise pesticide application may deteriorate this fruitful exchange of services between the two enterprises (Stein *et al*. 2017; Rollin and Garibaldi, 2019; Bareke and Addi, 2019; Sáez *et al*. 2020).

## RESULTS AND DISCUSSION

The average landholding size under the IFS models under study is depicted in Table 1. The majority of the land was devoted towards the crop enterprise while the average farmland devoted to dairy enterprise within the IFS models was around 0.10 ha. It was observed that the average farm size in Punjab under IFS-I, IFS-II, and IFS-III were 1.66, 3.44 ha, and 3.6 ha, respectively. It could be inferred that with an increase in landholding size in Punjab, farmers were diversifying towards additional components like mushroom and beekeeping. Four cropping patterns observed during *kharif* season in Punjab were paddy, paddy + maize, paddy + cotton, and paddy + vegetables. While in *rabi* season, farmers indulged in three cropping patterns: wheat, wheat + oilseeds, and wheat + vegetables. Farmers were also devoting a part of their land to cultivating fodder during *kharif* (bajra, jowar, and maize) and *rabi* (berseem) season.

**Table 1:** Average landholding size of IFS models in Punjab (in hectares)

| State | IFS models | Crop (ha) | Dairy (herd-size) | Mushroom (ha) | Beekeeping (beehives) | Total (ha) |
|---|---|---|---|---|---|---|
| | IFS-I | 1.56 | 12.00 | — | — | 1.66 |
| Punjab | IFS-II | 3.23 | 13.04 | 0.09 | — | 3.44 |
| | IFS-III | 2.76 | 12.66 | — | 304 | 3.60 |

***Source:*** *Compiled from field survey.*

Table 2 provides information regarding the average area devoted to different crops during *kharif* and *rabi* seasons in Punjab. Paddy and wheat were observed to be the prevalent crops under various IFS models and along with it, farmers were also found to be devoting a marginal piece of their farm for diversifying towards other crops like cotton, maize, oilseeds, vegetables, fodder.

The seed replacement rate in 2018 was announced as 12.86 per cent and 34.38 per cent for wheat and paddy in Punjab (Lok Sabha unstarred question, 2019). Hence, these data were considered while calculating the contribution of self-pollinated crops towards providing seeds for crop enterprise.

**Table 2:** Cropping rotation followed in the state of Punjab

| *Kharif* season | Average area (in ha) | *Rabi* season | Average area (in ha) |
|---|---|---|---|
| Paddy | 1.84 | Wheat | 1.95 |
| Cotton | 0.06 | Oilseeds | 0.09 |
| Maize | 0.07 | Vegetables | 0.04 |
| Vegetables | 0.02 | Fodder | 0.07 |
| Fodder | 0.16 | __ | __ |

***Source:*** *Compiled from field survey.*

The relationship between crop enterprise, dairy enterprise, household, and market of IFS-I model of Punjab via input-output coefficients has been described in Table 3. Vertically, the table states that output from crop enterprise worth ₹ 4,17,047 required inputs worth ₹ 1,82,476 which was fulfilled from crop, dairy, household, and market sectors to the respective tune of ₹ 9,136, ₹ 8,921, ₹ 76,562 and ₹ 87,857. Similarly, for dairy enterprise, the output of ₹ 12,00,610 used inputs from crop (₹ 33,171), household (₹ 77,602) and market sector (₹ 6,99,198). As per the findings of Table 1, the respective sum of input-output coefficients for crop and dairy enterprises were estimated to be 0.438 and 0.675, suggesting that for every one-rupee output generated from crop and dairy enterprise, 43.8 paise and 67.5 paise worth of inputs were being provided from within the IFS model. This in turn revealed that the dairy enterprise was more self-sufficient in providing inputs for itself than the crop enterprise as the sum of input-output coefficients was closer to one. It could also be interpreted that crop enterprise was more beneficial than dairy enterprise as it was generating more per rupee gross returns than the latter. The input-output linkage between crop and dairy (0.028) was stronger than the input-output linkage between dairy and crop (0.021). This table also reflects the utilization pattern of output when read horizontally. For crop enterprise, the total produce (₹ 4,17,047) was divided into the consuming sectors of crop, dairy, household, and market. Their respective shares in disposal were found to be 2.19, 7.95, 14.28, and 75.57 per cent. Similarly, from the dairy sector, the output was distributed into the consuming sectors of the crop (0.74%), household (8.85%), and market (90.40%). The marketable surplus being sold in the market sector was the only share from the crop and dairy products that were generating monetary returns as the consuming sectors were a part of the farming system hence, instead of generating income they were saving farmers from incurring it as costs. Out of the total labour utilized in the IFS-I model, the family labour contributed 32.3 per cent while the majority of the workforce (67.7%) was met by the hired labour.

**Table 3:** Transaction matrix for crop + dairy model in Punjab (₹ per farm per year)

| Producing sectors | Consuming sectors | | | Market | Gross returns |
|---|---|---|---|---|---|
| | Crop | Dairy | Household | | |
| Crop | 9136 (0.022) | 33171 (0.028) | 59558 (0.232) | 315182 | 417047 |
| Dairy | 8921 (0.021) | — | 106278 (0.414) | 1085411 | 1200610 |
| Household | 76562 (0.184) | 77602 (0.065) | 82742@ (0.323) | 173798# | 256540 |
| Market-oriented input | 87857 (0.211) | 699198 (0.582) | — | — | — |
| Total cost | 182476 (0.438) | 809971 (0.675) | — | — | — |

***Note:*** *Figures in parentheses are input-output coefficients, @ indicates the total contribution of family labour, # indicates the total contribution of the hired labour*

The input-output relationship between the sectors of the crop, dairy, mushroom, market, and household for the IFS-II model of the Punjab state has been discussed in Table 4. It was found that the output from the crop (₹ 7,30,810) was contributed by crop (₹ 11,215), dairy (₹ 9,694), and household (₹ 91,131), and market sector (₹ 86,026). For the dairy enterprise, the gross return (₹ 11,96,829) was respectively contributed by crop, household, and market-oriented inputs worth ₹ 42,616, ₹ 69,401, and ₹ 7,81,885. In the case of a mushroom enterprise, the endowments of inputs from households (0.353) towards the output were found to be higher than the contributions from market-oriented (0.258) and crop enterprises (0.054). The sum of input-output coefficients indicates that dairy (0.747) and mushroom enterprise (0.665) were highly self-sufficient within the farming system in comparison to the crop enterprise (0.271). It can be interpreted

**Table 4:** Transaction matrix for crop + dairy + mushroom model in Punjab (₹ per farm per year)

| Producing sectors | Consuming sectors | | | | Market | Gross returns |
|---|---|---|---|---|---|---|
| | Crop | Dairy | Mushroom | Household | | |
| Crop | 11215 (0.015) | 42616 (0.036) | 29950 (0.054) | 32274 (0.106) | 614755 | 730810 |
| Dairy | 9694 (0.013) | — | — | 115940 (0.379) | 1071195 | 1196829 |
| Mushroom | — | — | — | 18339 (0.060) | 535890 | 554229 |
| Household | 91131 (0.125) | 69401 (0.058) | 195474 (0.353) | 99094@ (0.324) | 206517# | 305611 |
| Market-oriented input | 86026 (0.118) | 781885 (0.653) | 143014 (0.258) | — | — | — |
| Total cost | 198066 (0.271) | 893902 (0.747) | 368438 (0.665) | — | — | — |

***Note:*** *Figures in parentheses are input-output coefficients, @ indicates the total contribution of family labour, # indicates the total contribution of the hired labour.*

**Table 5:** Transaction matrix for crop + dairy + beekeeping model in Punjab (₹ per farm per year)

| Producing sectors | Consuming sectors | | | | Market | Gross returns |
|---|---|---|---|---|---|---|
| | Crop | Dairy | Beekeeping | Household | | |
| Crop | 17570 (0.027) | 51007 (0.041) | 4066 (0.004) | 72793 (0.240) | 505893 | 651330 |
| Dairy | 9411 (0.014) | — | — | 108694 (0.358) | 1131758 | 1249863 |
| Beekeeping | 4880 (0.007) | — | — | 11928 (0.039) | 1330108 | 934851 |
| Household | 109562 (0.168) | 72077 (0.058) | 181847 (0.195) | 98606@ (0.325) | 204620# | 303226 |
| Market oriented input | 159156 (0.244) | 766641 (0.613) | 88421 (0.095) | — | — | — |
| Total cost | 300580 (0.461) | 889724 (0.712) | 274334 (0.293) | — | — | — |

***Note:*** *Figures in parentheses are input-output coefficients, @ indicates the total contribution of family labour, # indicates the total contribution of the hired labour.*

that mushroom and dairy enterprises have better co-dependence within the sectors of the IFS-II model.

For the IFS-III model, the relationship between crop, dairy, beekeeping, market, and household sectors has been discussed via transaction matrix in Table 5. It was found that for every one-rupee output from crop enterprise, inputs were procured from itself (2.7 paise), dairy (1.4 paisa), beekeeping (0.7 paisa), household (16.8 paise), and market (24.4 paise). In the case of a dairy enterprise, the input suppliers were crop (4.1 paise), household (5.8 paise), and market (61.3 paise). For beekeeping, the input suppliers were crop, household, and market with their corresponding shares of 0.4 paisa, 19.5 paise, and 9.5 paise towards every one rupee of output (honey and bee-wax). It was concluded that the dairy enterprise was more capable of channeling the inputs from within the farming system as the sum of the input-output coefficient was closer to one. The present study aligns with the research findings of Shalander (1998), Arya and Kalla (1992), and Sangpuii (2017).

## CONCLUSION

It could be concluded that there exists a certain degree of interdependence among the components of the three integrated farming system models of Punjab under study. Wherein the sum of input-output coefficients for dairy under all the models and mushroom enterprise under IFS-II were closer to one and self-sustainable. The overall forward linkages (crop-livestock) were revealed to be stronger than the backward linkages (livestock-crop) under all the three IFS models of Punjab. It was also found that crop sector was unable to meet the round-the-year fodder demand. Majority of the labours throughout the IFS models were hired-in from the market and was leading to increase in out-of-pocket costs for the farmers. The forward relationship between crop-dairy was observed to be higher than the dairy-crop input-output linkage due to two major reasons: (1) synthetic agrochemicals have replaced FYM and (2) heavy mechanization has limited the dependence of farming on draught power. To increase the forward and backward linkage between crop and dairy enterprise, herd size should be improved, dependence on agrochemicals should be reduced and the share of fodder crops in the cultivated area should be increased to fulfill the requirements of the dairy enterprise. It was also revealed that farmers sold more than 50 percent of their products from different components within the three IFS models under study, with no sign of distress sale. The forward integration from crop to other sectors was found to be much stronger than the backward integration, suggesting that steps should be taken up for strengthening the backward linkages as well. Adoption of mushroom and beekeeping enterprise with the crop + dairy IFS model, lead to some improvement in the linkages between crop and dairy sector, suggesting that adoption of more mutually benefitting enterprises help in achieving self-reliance for the integrated farming systems under study. Farmers could benefit from adoption of more enterprises under their model, hence, efforts could be made in promotion of adoption of IFS models with more number of sub-enterprises.

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