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Evaluation of farming systems of degraded lands of Yamuna ravines in Central India for income generation and sustainable livelihoods

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ABSTRACT

Among the various forms of land degradation, ravines are the worst manifestation of terrain deformation by water along with several river systems in alluvial zones of India. The households inhabiting ravine–affected areas have poor socio–economic status as well as poor resource endowment for livelihood. Though many studies have been conducted regarding socio–economic analysis of farming systems in India, there is a dearth of such studies of ravine affected areas for understanding income generation from these systems and dynamics of change in income due to change in number of farming system components, knowing the most profitable farming system, and suggest ways and means to make the profitable systems more sustainable. Based on primary data of sampled 320 farmers of the area, crop–horti–livestock farming system was identified to be the most profitable as compared to crop only and crop–livestock farming systems for marginal, small and medium categories of farmers. Increase in number of farming components decreased the contribution of off–farm sources of income for all farm categories; however, the agricultural income even from the most profitable farming system was not sufficient for marginal farmers to carry it above the poverty line of ₹ 32 only in rural areas. Suggestions have been made for augmenting agricultural income, particularly of the marginal and small farmers, and making it sustainable.

1. INTRODUCTION

How to feed the world is an increasingly urgent and looming concern voiced by many people, from local community groups to national and international governing bodies. The country's population is expected to reach 1643 Million by the year 2050 (UN DESA, 2019) and to feed such a huge population, approximately 349 Mt of food grains will be required annually (Thornton, 2015). It is anticipated that net cultivable area available in 2050 would be 137 Mha (Gamit *et al.,* 2015). However, land degradation is one of the most serious impediments in meeting food demand and for sustainability in agricultural production (Sharda *et al.,* 2019; Meena *et al.,* 2020). As per the latest database on land degradation, about 120.72 Mha of country's total geographical area is subjected to various forms of land degradation (NAAS, 2010). Among the various forms of land degradation, ravines are the worst manifestation of terrain deformation by water. Land degradation due to ravines is a major problem along several river systems in alluvial zones of India. Though ravines and gullies occur along all major river systems of India, the largest incidences are found in Rajasthan (1884.92 sq km), Uttar Pradesh (1502.06 sq km) and Madhya Pradesh (1481.11 sq km) (GoI, 2010). The lands near to gully head in ravines are dominated by agricultural land use, while pastures and open forests dominate side slopes and gully beds (Pande *et al*., 2018). The households inhabiting ravine affected areas have poor socio–economic status as well as poor resource endowment for livelihood. They are mainly dependent on agriculture as the main occupation (Mudgal, 2005; Pani, 2017). Lack of livelihood security compels the members of poor families to migrate to cities from villages in search of employment during distress. Thus, their lands are either kept fallow or cultivated with low cropping intensity. These bare lands accelerate soil erosion, enhance runoff of rainwater resulting in siltation of water bodies and loss of biodiversity, thereby contributing to environmental degradation.

Food and sustainable rural livelihood security can be achieved through potential use of degraded land, improvement in productivity of crop and livestock, saving in cost of production, increase in cropping intensity, diversification towards high–value crops, and improvement in real prices received by farmers. Identification of appropriate integrated farming systems has been proposed as one of the best approaches to achieve higher growth in agriculture and livelihood (National Commission on Farmers, 2005). Integration of different farm enterprises provides sustainable livelihood in terms of increased food production, improved net income and productivity, and reduced income imbalance between agricultural labourer and urban factory worker.

This study aims to provide scientific information to different stakeholders of agriculture for improving household income and sustainable livelihood security inhabiting ravine–affected areas by analysing the existing farming systems. Analysis of farming systems provides a better platform for introduction of highly sophisticated technology on one hand, and the physical, social and economic factors on the other. Further, understanding the socio–economic status of stakeholders leads to adoption of cultivation practices in different ways as per their risk–bearing capacity with the use of available resources. A large number of researchers have opined that there is a need to understand and analyse existing farming systems to quicken the pace of agricultural development (Sajeev *et al*., 2010; Saha and Bahal, 2010; Torane *et al*., 2011). Inability to understand the existing farming systems might often lead to failure in adoption of new technology (Feder *et al*., 1985). Though many studies have been conducted regarding socio–economic analysis of farming systems in India (Ramrao *et al.*, 2005; Singh *et al*., 2011; Singh *et al*., 2017), there is a dearth of studies on the socio–economic analysis of farming systems in ravines and adjoining areas, particularly in Yamuna ravine area. Therefore, a location–specific study was taken up for economic evaluation of farming systems adopted by different farm size categories in the degraded land of Yamuna ravine in state of Uttar Pradesh to know the income status and dynamics of change in income with change in number of components in the adopted farming systems, to identify the most profitable farming systems, and to suggest ways and means for making the profitable farming systems sustainable for their livelihoods.

2. MATERIALS AND METHODS

Sampling and Data Collection

For data, two districts, namely Agra and Etwah were selected purposively, where most of the ravine lands are spread. Four blocks, namely Fatehabad and Bah from Agra, and Badpura and Chakar Nagar from Etawah district, were identified based on the maximum ravine area in these districts. Eight villages (two villages from each selected block) were selected from the districts. For selection of the villages, a list of ten villages having severe ravine problem was prepared for the respective *Tehsil*. From the list, two villages were randomly selected. Forty respondents were selected for detailed data collection from each village (total sample size: 320) having different categories of households (farming–92% as well as landless–8%) through random sampling. A well–structured schedule was developed and used to collect desired information from these households. Detailed information on various parameters was collected through different methods such as focus group discussion, key informants interview, transect walk and field observations. Furthermore, household survey was conducted to elicit primary information on required parameters using pre–tested schedule. The collected data were analyzed by using descriptive statistics such as mean, percentage and frequency. We used education index to know education level of households and the following equation was employed to calculate education index.

$$\text{Education index} = \Sigma wifi \;/\; \Sigma fi$$

Where, i (education attained) = 0, 1, 2, 3… 5, *i.e.* Illiterate = 0, Primary = 1, Middle = 2, Matric = 3, Twelfth = 4 and Graduate = 5, wi = weights (0 to 5) and fi = No. of households.

Cost and Return Analysis

Cost and returns method was used for analysing economics of the existing farming systems. Net return of each crop was calculated by estimating the difference between gross return and total cost. To estimate total cost, we included cost incurred on seeds, fertilizer, plant protection chemicals, hired human labour, farm machinery and implements, taxes, cess, irrigation charges, and interest on working capital. Gross return was calculated by multiplying the quantity of the crop produce with the unit price received in the year 2017–18. The amount of produce kept for home consumption was also taken into account for the calculation of the gross return. The net income per farm household from crop cultivation was calculated by adding net return of each crop cultivated by the farmer divided by the number of the sample farmers.

$$\text{Gross return} = (\text{Quantity of produce} \times \text{price of produce}) + (\text{Quantity of by} - \text{produce} \times \text{Price of by} - \text{produce})$$

$$\text{Net income} = \text{Gross return} - \text{Total cost}$$

$$\text{Gross income from farming system} = \Sigma_{i=1}^{n} Q_i P_i$$

Where, Q_i is the physical output (main and by–product) of i^{th} component of farming system and P_i is the price of i^{th} output. Net income from livestock activities was calculated by subtracting total cost from gross earnings of livestock products milk and *ghee*. Under total cost, we considered expenditure cost incurred on livestock maintenance such as feed and fodder, mineral mixture, medicine and depreciation of owned farm machinery, buildings and animals. The total earnings included the value of milk used for household consumption.

3. RESULTS AND DISCUSSION

Socio−Economic Profile of Respondents Under Different Farming Systems

Crop−livestock was the predominant farming system among existing farming systems adopted by about 66% of households (Fig. 1) which was followed by crop−livestock−horticulture farming system (16%). Rest constituted of crop only farming system (10%) and livestock−labour−business (8%), the latter adopted by the landless.

The socio−economic status of respondents revealed that about 76% of them were marginal and small farmers, and about 8% were landless (Table 1). The average land holding size varied from 0.43 ha for marginal farmers to 2.68 ha for medium farmers and overall, it was 1.07 ha. The average family size was largest (7.7) in the crop−livestock farming system, followed by the crop−horti−livestock farming system (7.2).

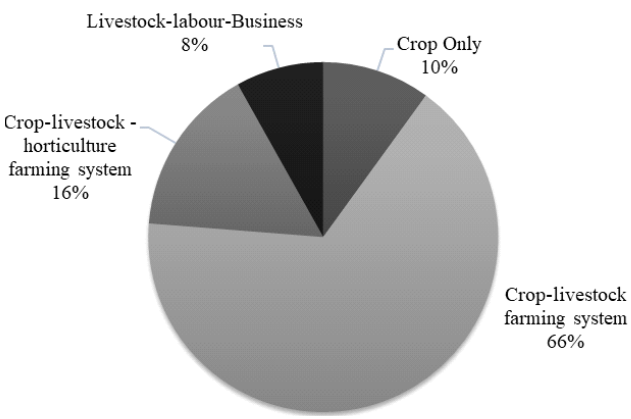

Fig. 1. Major farming systems adopted by the percentage of respondents

Education level commonly correlates positively with adoption of a new intervention (Benal *et al*., 2010; Singh *et al.,* 2011; Mondal *et al.,* 2013). The household educational index was lowest in case of all categories of farm size in the crop only farming system, whereas it was highest in the crop−horti−livestock farming system. Similarly, the highest migration of family members was in the crop only farming system in case of all categories of farm size, and the least in crop−horti−livestock farming system. The crop−horti−livestock farming system provided maximum employment per year followed by crop−livestock farming system.

The average cropping intensity was 152% of the sampled farmers. The highest cropping intensity was of marginal farmers' crop−horti−livestock farming system (192%), and lowest of medium farmers' crop only farming system (120%). Cropping intensity has increased from 149.4% to 156.1% over the last decade in Uttar Pradesh (UP) state indicating intensification in usage of agricultural land as well as inputs (GoI, 2021). Cropping intensity in the study area and UP state has been higher than the national average, but it is much lower than some other agriculturally developed states such as Punjab (190.1%) and Haryana (183.8%). The data of the present study shows that there is a negative correlation between cropping intensity and farm size, irrespective of the farming system adopted (Table 1).

The livestock sector has a critical role in income, employment generation and food security of agricultural households (Birthal *et al.,* 2017). Cows and buffaloes are the major livestock maintained by all categories of the respondents (Table 1). Among ruminants, goats are owned by farmers, particularly of marginal and small categories. The livestock population (cows and buffaloes) varied from

Table: 1
Socio−economic characteristics of sample farmers in existing farming systems (FS)

	Crop only FS			Crop−livestock FS			Crop−horti−livestock FS		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
Sample size	17	9	6	112	64	36	27	15	8
Family size, No.	6.23	7.2	7.3	7.9	7.4	7.4	7.5	6.7	7.35
Household educational index	1.11	1.15	1.21	1.31	1.22	1.25	1.93	1.33	1.25
Employment, man days^{-1}yr^{-1}	185	175	170	378	355	309	423	356	315
Migration, No. of members/household	2.1	1.8	0.85	1.7	1.28	0.55	0.9	0.8	0.3
Migration, %	33.7	25.0	11.6	21.5	17.3	7.4	12.0	11.9	4.1
Farm size, ha	0.5	1.41	3.1	0.43	1.32	2.65	0.39	1.16	2.47
Cropping intensity, %	138	126	120	174	156	147	192	165	162
Desi cows, No./household				0.39	1.05	0.4	0.25	1	0.6
Desi buffaloes, No./household				0.92	1.3	1.9	0.5	0.75	1.2
Murrah buffaloes, No./household				0.22	0.35	0.38	0.25	0.3	0.3
Other animals*, No./household				2.4	1.26	1.8	1.5	1.75	1.55
Goat, no./household				1.8	2.1	0.3	0.8	0.15	0.00
Kids, no./household				0.8	1.1	0.1	0.3	0.1	0

**Calves and drought animals*

1.00 household^{-1} for marginal farmers of the crop–horti–livestock farming systems to 2.68 household^{-1} for medium farmers of the crop–livestock farming system.

Murrah buffalo is the best breed for high milk yield, but its percentage share in total population of buffalo owned by the sampled farmers was very low. It is important to note that among the sampled respondents, medium sized farms preferred buffaloes more than cows, whereas, marginal and small sized farms preferred cows and small ruminants (goats) more than buffaloes (Table 1). Medium farm's ownership of goats was negligible or none. The average yield of milk per animal was 3.6 lit day^{-1} for cow, 6.0 lit day^{-1} for *desi* buffalo and 8 lit day^{-1} for Murrah buffalo. This average milk yield lags behind that of states such as Punjab, Haryana and Gujarat. Population of cross–bred cows and sheep was not present in the study area.

The farmers as well as the landless households are traditionally maintaining livestock as a reliable source of income and cash reserve in times of emergency. Usually, farmers of the study area do not invest highly in purchasing dairy animals. In the absence of high milk yielding cross–bred livestock and lack of technical support, as the study areas are in interior places where government's extension services are either absent or are of extremely poor quality, most of the farmers are getting meagre livestock income. The major factors responsible for the low productivity of livestock perceived by the dairy farmers were lack of technical guidance for standard husbandry practices (81%); poor breeding and health care services (80%); nutritional deficiency due to shortage of feed and fodder (55%); inefficient milk collection and marketing (57%); lack of milk processing unit (79%) and unavailability of credit facilities (78%).

Farm–Size–Wise Percentage Area Under Major Crops in Different Farming Systems

Kharif and *rabi* are only two cropping seasons in the Yamuna ravine area, among which *rabi* season is the prime cropping season. The farmers preferred to keep their land fallow during the *jayad* season (intervening season between *rabi* and *kharif* seasons). Wheat was the major crop in *rabi* season followed by mustard, and *bajra* was the only single crop in *kharif* season. The major determinants of the cropping pattern comprehended by the farmers were assured irrigation facility and rainfall distribution (68%), livelihood security (61%), wildlife attack (95%) and social caste system (42%).

Farm–size–wise percentage of gross cropped area (GCA) under different farming systems is depicted in Table 2. Out of total GCA, maximum share was under *bajra* crop in *kharif* season, whereas wheat and mustard were prominent shareholding crops during *rabi* season. In case of cereal crops, the maximum share (under *bajra* and wheat) was in crop–livestock farming system followed by crop–horti–livestock farming system. On the other hand, share of oilseed crop mustard in GCA was maximum in case of crop only farming system followed by crop–livestock and crop–horti–livestock farming system, irrespective of farm size.

It is also evident from Table 2 that there is a negative correlation between the share of cereal crops in GCA and landholding size, except in case of crop–horti–livestock farming system, where the trend is opposite. A similar trend was also observed in case of 'other vegetables', whereas a positive correlation exists in case of oilseed (mustard). Further, it is important to note that the share of mustard crop decreased as the number of components increased (livestock and vegetables). The evidences suggest that marginal and small farmers were more dependent on *bajra* and wheat crop for their nutrition, food and fodder security when vegetables (as cash crops) are not component of farming system. The medium category of farmers was more interested in growing mustard and to some extent potato as cash crops to meet their livelihood security. Among vegetables, potato is a widely grown crop in the study area as well as in UP State. In the study area, farmers were growing only vegetables under horticulture. Apart from potato, other vegetable crops like chilli, coriander leaf, *ratalu* (yam), onion seedling, *bhindi* (lady finger), pumpkin, radish and brinjal were grown on 1.85 % of GCA.

Economic Analysis of Farming Systems

Crop farming system

The average annual income of farmers by different farm size categories from crop cultivation and off–farm sources is depicted in Table 3. The average annual gross

Table: 2
Farm–size–wise percentage area of GCA under different crops in different farming systems (FS)

Crops (season)	Crop only FS			Crop–livestock FS			Crop–horti–livestock FS		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
Bajra (*kharif*)	39.5	28.6	34.2	48	44.8	37.0	35.8	48.0	41.6
Wheat (*rabi*)	45.2	43.2	29.6	43	39.3	30.6	29.2	27.2	31.9
Mustard (*rabi*)	15.3	28.2	36.2	9	15.9	32.4	2.9	8.5	15.8
Potato (*rabi*)	–	–	–	–	–	–	5.9	13.9	10.7
Other vegetables (*kharif* and *rabi*)	–	–	–	–	–	–	26.2	2.4	–
Gross crop area (GCA), ha	12	16	22	84	132	140	20	29	32

Table: 3
Cost and returns of crop farming system

Farm size category	Average farm size (ha)	Average annual gross income (₹)		Total average annual gross income (₹)	Percentage contribution in total average annual net income (%)	
		Crops	Off–farm		Crops	Off–farm
Marginal	0.50	41844 (18263)	85000 (85000)	126844 (103263)	17.69	82.31
Small	1.41	105271 (45240)	79000 (79000)	184271 (124240)	36.41	63.59
Medium	3.10	206427 (91164)	41000 (41000)	247427 (132164)	68.98	31.02

Figures in parenthesis are average annual net incomes. Average annual total cost can be estimated by deducting average annual net income from respective average annual gross income.

income from crop cultivation was estimated to range from ₹ 41844 for marginal farmers to ₹ 206427 for medium farmers. Therefore, the average annual gross income of a medium farmer from crop cultivation was nearly five times higher than to that of a marginal farmer; of a small farmer was about two and half times. The average annual net income ranged from ₹ 18263 to ₹ 91164, and the ratio of these two incomes was same as that of gross incomes.

The off–farm income (particularly wage–earning) contributes about 82% to the annual net income of marginal farmers practicing crop only farming system. This share reduces notably with an increase in farm size. Therefore, as compared to the medium farmers, income from off–farm sources is a major income of marginal and small farmers, and it supplements their lower agricultural income, which is due to lower size of their land holding. Overall, results indicate that the share of income from crop cultivation in annual net income from all sources increases with the size of landholdings in case of crop only farming system in Yamuna ravine area (Chakravorty *et al*., 2019).

Per day household and per capita per day income

Estimated per–day household income from crop cultivation was observed to range from ₹ 50 for marginal farmers to ₹ 250 for medium farmers (Table 4). The per–day per– capita income from agriculture was estimated to be ₹ 8 for marginal farmers, ₹ 17 for small farmers and ₹ 34 for medium farmers. According to the C. Rangarajan Committee's estimate, a person who has per day purchasing power of ₹ 32 only in rural areas is defined as living below the poverty line (Mishra, 2014). Based on this poverty line standard, the evidence showed that the marginal and small farmers living in ravine–affected areas of the Yamuna river cannot meet their daily basic requirements if they only depend on income from crop cultivation. Therefore, to meet their daily basic requirement of life, they depend on off–farm income to the extent of 64% to 82% (Table 3). The off–farm income boosted per–day and per–capita income of marginal and small farmers to greater than the poverty line (Table 4). However, in case of medium farmers, crop income was sufficient for their survival, and hence their dependency on off–farm sources for income was only 31% (Table 3).

Table: 4
Farm–size wise per–day and per–capita income of farm house holds in crop only farming system

Particulars	Marginal	Small	Medium
Per–day household income (₹)			
Crop	50	124	250
Off–farm	233	216	112
Total	283	340	362
Per–capita per day income (₹)			
Crop	8	17	34
Off–farm	37	30	15
Total	45	47	50

Crop–livestock farming system

In crop–livestock farming system, crop production contributed about 17% to 60%, and livestock contributed about 26% to 33% to the total average annual net income of farmers (Table 5). The contribution of both components together ranged from 43% to 93%. The contribution of off–farm sources ranged from 7% to 57%. Therefore, with addition of livestock component with crop cultivation, the contribution of off–farm income decreased from 63–82% (Table 3) to 37–57% (Table 5) of marginal and small farms. The medium farmers generated the maximum average annual gross as well as net income of ₹ 199962 and ₹ 90851, respectively from crops among all categories of farmers, both of which were about 5 times and 2 times that of marginal and small farmers, respectively. In case of livestock component too, medium farmers generated the maximum average annual gross as well as net income. The maximum values (medium farmers) were 67–76% higher than the lowest values (marginal farmers). Gross as well as net incomes from both the components together of medium farmers were about 200% (*i.e.* three times) and 55% higher to that of marginal and small farmers, respectively.

In addition to higher income than crop only farming system, farming livestock with crop cultivation has several

Table: 5
Cost and returns of crop−livestock farming system

Farm size category	Average farm size (ha)	Average annual gross income (₹)				Total average annual gross income (₹)	Percentage contribution in total average annual net income (%)			
		Crops	Livestock	Total from farm	Off−farm		Crops	Livestock	Total from farm	Off−farm
Marginal	0.43	40511 (17939)	68602 (28571)	109113 (46510)	61533 (61533)	170646 (108043)	16.6	26.4	43.0	57.0
Small	1.32	103845 (46859)	99854 (44013)	203699 (90872)	52530 (52530)	256229 (143402)	32.7	30.7	63.4	36.6
Medium	2.65	199962 (90851)	114811 (50369)	314773 (141220)	11250 (11250)	326023 (152470)	59.6	33.0	92.6	7.4

Figures in parenthesis are average annual net incomes. Average annual total cost can be estimated by deducting average annual net income from respective average annual gross income.

other advantages such as efficient use and recycling of by−products like crop residues as animal feed and dung as manures, and the synergistic effect from the recycling leads to higher resource use efficiency and net income. This is evident from the study that despite a lower absolute average size of farm, the total average annual net income from agriculture is higher within same category of farmer when the farming system changes from only crop to crop−livestock farming system. In case of marginal farmers, the agricultural income was ₹ 18263 (Table 3) from an average farm size of 0.50 ha practicing crop only farming system, whereas the same income was ₹ 46510 (Table 5) from an average farm size of 0.43 ha practicing crop−livestock farming system. The increase was of 155%. Similarly, in case of small farmers, the agricultural income was ₹ 45240 (Table 3) from an average farm size of 1.41 ha practicing crop only farming system, whereas the same income was ₹ 90872 (Table 5) from an average farm size of 1.32 ha practicing crop−livestock farming system. The increase was of 101%.

Per day household and per capita per day income

The per−day household income from all sources varied from ₹ 296 for marginal farmers to ₹ 418 for medium farmers (Table 6). However, the per−day per−capita income from agriculture was ₹ 16 for marginal farmers, ₹ 31 for small farmers and ₹ 53 for medium farmers. Thus, despite an extra component in this farming system as compared to crop only farming system, all marginal and small farmers would still be below the poverty line if they solely depend on income from agricultural and allied activities. However, per−capita per−day income from agriculture and allied activities in this farming system was nearly two times that of the crop only farming system, particularly of the marginal and small farmers (182−200%), due to the extra (livestock) component. As a result, the off−farm part of this income reduced by 40−43%. Further, livestock acts as income insurance in crop−livestock farming systems. A study by DeSilva and Sandika (2012), especially of marginal and small farmers, found that if there is an emergency arising out of loss by crop or sudden need of cash, farmers depend upon

Table: 6
Farm−size wise per−day household and per−capita income of farm households in crop− livestock farming system

Particulars	Marginal	Small	Medium
Per−day household income (₹)			
Crops	49	128	249
Livestock	78	121	138
Agriculture and allied activities	127	249	387
Off−farm	169	144	31
Total income	296	393	418
Per−capita per day income (₹)			
Crops	6	16	34
Livestock	10	15	19
Agriculture and allied activities	16	31	53
Off−farm	21	18	4
Total income	37	49	57

selling animals such as male calves, old cows and goat. Additionally, diversification in agriculture can act as a mitigating factor against crop failure, and dairying is emerging as a better alternative in diversification, especially under mixed farming systems (Bharadwaj *et al.,* 2006).

Crop−horti−livestock farming system

Under this farming system, crop production contributed approximately 10% to 50% and livestock contributed about 20% to 27%, whereas, horticulture (vegetables) contributed 15% to 18% to the total net income of farmers (Table 7). Notably, the contribution of horticulture in total average annual net income was found maximum (18%) for marginal farmers, followed by the medium (17%) and small farmers (15%). In case of other two components, the trend was as per size of farm. The contribution of the three farming components together ranged from 50% to 95%. The contribution of off−farm sources ranged, accordingly, from 5% to 50%. Therefore, with addition of horticulture component to livestock and crop components, the contribution of off−farm income decreased from 37−57% (Table 5) to 34−50% (Table 7) of marginal and small farms. The medium farmers generated the maximum average annual gross as well as net income from crops among all categories of farmers, both of which

Table: 7
Cost and returns of crop−horti−livestock farming system

Farm size category	Average farm size (ha)	Average annual gross income (₹)					Total average annual gross income (₹)	Percentage contribution in total average annual net income (%)				
		Crops	Horticulture	Livestock	Total from farm	Off−farm		Crops	Horticulture	Livestock	Total from farm	Off−farm
Marginal	0.39	25136 (11135)	28362 (18788)	51473 (21379)	104971 (51302)	52000 (52000)	156971 (103302)	10.78	18.19	20.70	49.66	50.34
Small	1.16	76492 (34625)	31533 (19774)	82307 (35243)	190332 (89642)	46260 (46260)	236592 (135902)	25.48	14.55	25.93	65.96	34.04
Medium	2.47	162061 (77207)	43149 (26154)	98119 (42982)	303329 (146343)	8000 (8000)	311329 (154343)	50.02	16.95	27.85	94.82	5.18

Figures in parenthesis are average annual net incomes. Average annual total cost can be estimated by deducting average annual net income from respective average annual gross income.

were more than 6 times and 2 times that of marginal and small farmers, respectively. In case of livestock component too, medium farmers generated the maximum average annual gross as well as net income. The maximum values (medium farmers) were 91−101% higher than the lowest values (marginal farmers). In case of horticulture component, the difference was 39−52%. The maximum average annual gross (₹ 303329) as well as net income (₹ 146343) from agriculture was generated by medium farmers, which were about 3 times and 1.5 times that of marginal and small farmers, respectively.

Like the livestock component, the advantage of additional component of horticulture was significant in case of marginal farmers, but it was not in case of small farmers. It is evident from the study that despite a lower absolute average size of marginal farm, the total average annual net income from agriculture is higher within this category of farmer when the farming system changes from crop−livestock to crop−horti−livestock farming system. The agricultural income was ₹ 46510 (Table 5) from an average farm size of 0.43 ha practicing crop−livestock farming system, whereas the same income was ₹ 51302 (Table 7) from an average farm size of 0.39 ha practicing crop−horti−livestock farming system. The increase was of 10%. In case of small farmers, it was marginally less by 1%.

Per day household and per capita per day income

The per−day household income from all sources varied from ₹ 283 for marginal farmers to ₹ 423 for medium farmers (Table 8). But on per−day per−capita basis, income from all sources was calculated as ₹ 38, ₹ 56 and ₹ 58 for marginal, small and medium farmers, respectively, and from agriculture and allied activities exclusively, it was ₹ 19, ₹ 36 and ₹ 55, respectively. Thus, agricultural income of small and medium farmers of this farming system was sufficient to maintain them above the poverty line, but of marginal farmers, despite two more components then crop only farming system, was not sufficient. They still have to depend on off−farm sources, whose contribution is 50% out of ₹ 38 of per−day per−capita income. However, per−capita per−day income from agriculture and allied activities in this farming system is 16% to 19% higher to that of the crop−livestock farming system of the marginal and small farmers, due to the extra (horticulture) component. As a result, the off−farm part of this income reduced by 10% in case of marginal farmers, and but was almost unchanged in case of small farmers.

Table: 8
Farm−size wise per−day household and per−capita income of farm households in crop−horti−livestock farming system

Particulars	Marginal	Small	Medium
Per−day household income (₹)			
Crops	31	95	212
Horticulture (vegetables)	51	54	72
Livestock	59	97	118
Agriculture and allied activities	141	246	401
Off−farm	142	127	22
Total	283	372	423
Per−capita per day income (in ₹)			
Crops	5	14	29
Horticulture (vegetables)	7	8	10
Livestock	8	14	16
Agriculture and allied activities	19	36	55
Off−farm	19	19	3
Total	38	56	58

Soil and water conservation measures adoption

The soil and water conservation (SWC) measures are considered key to address the problems of low agricultural productivity and land degradation in India (Kumar *et al*., 2019). Percentages of sampled farmers who adopted various SWC on their farms have been depicted in Fig. 2. Results revealed that field *bunding* was adopted by about 43% of farmers on their farm. Crop rotation and summer ploughing were adopted by about 35% and 15% of farmers, respectively. Further, farmers, through interactions, suggested that SWC measures of *bunding*, check dam, gully plugging, farm pond and forestry tree plantations should be imple-

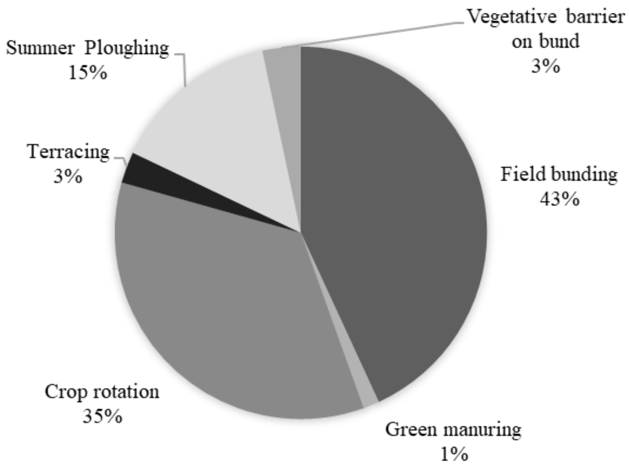

Fig. 2. Soil and water conservation measures adopted by sampled farmers

mented extensively in ravine areas by the Government, as they would ultimately lead to improving agricultural production, farmer's income and livelihood sustainability. In addition to this, huge crop losses due to wild animal/stray cattle reported by most of the respondents, as well as by Kurothe (2018) in such areas, need to be drastically reduced. Therefore, wire/solar fencing is necessarily required to keep off wild animals/stray cattle with the provision of additional subsidy. This would help in sustaining the income of the farmers from agriculture, especially of marginal and small, to raise it above the poverty line and reduce their dependence on off–farm income for it.

Major vegetation in Yamuna ravine area

Yamuna's ravine ecosystem is an important factor in the socio–economics of the inhabitants. The predominant vegetation comprises *Vilayati Babul* (*Prosopis juliflora*) followed by *Desi Babul* (*Acacia nilotica*), thorny legumes, *Euphorbias* and dwarf grass species. A few multi–purpose trees present on field bunds and boundaries are Neem (*Azadirachta Indica*), Papdi (*Holopteila integrifolia*), Shisham (*Dalbergia sissoo*) and white Siris (*Albizia lebbeck*). A significant section of the inhabitants (small, marginal farmer and landless) continue to depend on ravines for fuelwood and fodder (grazing) as these multi–purpose trees are not able to meet the demand of these inhabitants. Silvi–pastoral and agroforestry systems are not being adopted in the study area. Dependency on forest vegetation needs to be reduced for sustainability of their livelihood by adoption of these systems. These systems can play a major role in bringing the desired level of diversification in farming along with livelihood sustainability (Singh *et al.*, 2020).

Potential use of degraded ravine land

The non–arable ravine land can be economically utilised through bamboo and Anjan grass–based silvi–pasture system to meet the fodder needs apart from providing a supplementary source of regular income to the farmers. Bamboo has been found to have great conservation as well as income generating potential (> ₹ 50,000 $ha^{-1}yr^{-1}$) in the Yamuna ravine, and is best suited for gully head and bed stabilization (Pande *et al.,* 2012). The degraded ravine land can be utilised by adopting *Aloe vera* intercropping for improved productivity of *ber* plantations with suitable SWC measures as this technology can generate income of ₹ 40,000 $ha^{-1}yr^{-1}$ (Mohapatra and Jha, 2008). The technologies for potential use of ravine land are presently available in the country, but these technologies are not adopted by the farmers due to inadequacy of extension services, farmer's unawareness about technologies and lack of market access. (Gomiero, 2016; Dagar and Singh, 2018) Thus, there is a need for creating awareness among these households for successful adoption of recommended technologies.

4. CONCLUSIONS

The study was taken up to generate information regarding socio–economic characteristics of households of the Yamuna ravine area, the economics of major farming systems being exercised by them for their livelihood, and accordingly identifying the most profitable one among them having potential for adoption by the non–users in the same ravine land. The results of the study indicate that marginal and small farmers of the ravine area practicing crop only farming system are earning well below the poverty line income on per–capita per–day basis from agriculture, and therefore have to significantly depend (64–82%) on off–farm income sources for their livelihood. With addition of livestock and horticulture components to crop cultivation, this dependence decreases to 34–50%. Therefore, marginal and small farmers need to be supported for upgrading from single to multi–components farming system as they have been recommended as one of the best approaches to achieve higher growth in agriculture and livelihood (Singh *et al.*, 2009; Ponnusamy and Devi, 2017; Singh *et al.*, 2017). Also, upto 50% dependence on off–farm sources from multi–components farming system for income needs to be decreased with extensive implementation of soil and water conservation measures that have the potential to reduce soil erosion losses causing loss of income (Sharda *et al.*, 2010; Sharda and Dogra, 2013). Adoption of silvi–pastoral and other suitable agroforestry systems must be encouraged for their utilization to augment the important livestock component, in particular, and farming systems, in general. Also, reasons for low livestock productivity revealed by the study need to be addressed. This study would help different stakeholders to understand existing farming systems, and identifying strategies for development of agriculture and improving farmer's income in the Yamuna and other ravine areas.

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