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Intensification of Tree Cultivation in Cropland Based Agroforestry Systems- Role of Socio-economic Factors

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Abstract: Agroforestry is one of the sustainable land uses which have the potential of fulfilling the food as well tree based needs of the increasing population simultaneously from the same unit of the land. Intensification of agriculture through new high yielding cereal varieties, irrigation, pesticides and fertilisers has many concomitant environmental hazards. Thus emphasis has shifted on intensification of tree cultivation on cropland. The studies on factors affecting tree intensification on cropland are almost non-existent. Hence present study on role of socio-economic factors was undertaken in Mandi district of Himachal Pradesh. Multistage sampling was followed to select the households. The data were collected using a pre-structured schedule and personal interviews with the head of the household. Multistage sampling was used to select households. Tree intensification was defined in terms of the number of trees per hectare on the crop land of the farmers. The farmers were categorised into two groups: low intensity adopters (farmers with 1-78 trees/ha) and high intensity adopters (farmers with >78 trees/ha). The association between the dependent variable (low intensity adopters -farmers with 1-78 trees/ha) and high intensity adopters-farmers (>78 trees/ha) and different independent variables was found using Chi-square test of association. Logistic regression analysis was used to identify the key variables influencing tree intensification. The study shows that education level of the head of household, cropping intensity, household food sufficiency, household livestock holding, quantity of tree produce sold, livestock holding and level of restrictions on grazing after crop harvest significantly and positively influenced the intensification of tree cultivation. However, the farmers with large sized cropland holdings were less likely to go for tree intensification. Based on logistic regression model, more emphasis needs to be given to restrict on-farm grazing after crop harvest followed by encouraging linkage of tree products for better marketing so as to increasing the intensity of tree cultivation in cropland agroforestry systems. The influence of the size of cropland holding had also significant but negatively influence of tree intensification implies small holders are more likely to have more intensification than the larger. Therefore, specific efforts need to be made to encourage large holder to intensify tree cultivation. The study implies that socio-economic factors need to be considered while formulating tree intensification strategies.

Keywords: Households, Adopters, Diversification, Sustainable

By the year 2030, it is estimated that world population will be 8.5 billion leading to feed 800 million more people in the world compared to that of 2019 (UN 2019). This would increase the demand for food production to meet the needs of the increasing population. In addition will create more pressure on forests for tree products and possible diversion of forests for agriculture to produce more food leading to deforestation. In past, the intensification of agriculture in the form of the green revolution has resulted in an increase in food production from existing arable land through the use of new high yielding cereal varieties, irrigation, pesticides and fertilisers. Although it helped in meeting the food requirement of increased population, however, it resulted in environmental pollution, land degradation and decrease in basic productive capacity of the ecosystem. Thus productivity achieved during the green revolution could no longer be sustained. Thus the challenge became much bigger due to the decline in environmental resource base (soil erosion, water shortage, desertification, acid rain, global warming). Sustainable development strategies have gained importance after Brundtland's (1987) “Our Common Future” and were further affirmed by the World Summit on Sustainable Development (UN 2002). Agroforestry - a land use involving growing of trees with agricultural crops and/or livestock rearing, seems to hold the potential to solve the problems of rural development by fulfilling the needs of rural people for tree as well as food products through sustainable use of the land. Moreover, it has a capacity to divert pressure from existing forests and increase effective tree cover at local, regional and global level. Since few years agroforestry has also received impetus as strategy for climate change mitigation and adaptation. Agroforestry systems act as effective carbon sinks (IPCC 2000, Jose and Bardhan 2012). There has been an overall increase in area under agroforestry at the global level in 2000-2010 (Zomer et al 2014). The overall population in the world living in agroforestry landscape has increased from 746.7 million to 837.6 million during 2000-2010 (Zomer et al 2014). Thisimplies that more farmers have realized the importance of agroforestry and consequently adopted it. Now the emphasis is on intensification of tree component of agroforestry, rather crop components of Agroforestry, so that potential of trees to benefit crops, provide tree products, reduce deforestation and provide environmental benefits could be reaped to the maximum. There are many studies in various parts of the world to investigate the factors affecting agroforestry adoption. Many programmes and projects have been implemented in the various parts of the world to intensify the tree cultivation in agroforestry. Notwithstanding, there is meagrely any study to investigate the factors affecting intensification of tree cultivation in agroforestry, specifically the crop land agroforestry. Therefore, the study on the role of socio-economic factors on intensification of tree cultivation cropland agroforestry was under taken.

MATERIAL AND METHODS

The study was carried out in Mandi district of Himachal Pradesh. The data were collected using a pre-structured schedule and personal interviews with the head of the household. Multistage sampling was used to select households. Out of five forest divisions in the district, two forest division namely Joginder Nagar and Suket, were selected purposely as these contain both hilly and plain topography. A list of Joint Forest Management (JFM) programme and non-programme villages for each of hilly and plain areas was prepared with the help of divisional forestry staff of each selected forest division. Two villages from each subcategory (JFM programme and non-programme villages) for hilly and plain topography villages were chosen in each selected forest division using simple random sampling with replacement method. In this way, there were eight sample villages in each of selected forest divisions and 16 villages in total. A list of households in each of the selected villages was prepared by employing data collectors. One-thirds of households were taken as the sample from each selected village. Tree intensification was defined in terms of the number of trees per hectare on the crop land of the farmers. The median number of trees was 78. Thus the dependent variable (type of farmers) was categorised into: low intensity adopters (farmers with 1-78 trees/ha) and high intensity adopters (farmers with >78 trees/ha). The association between the dependent variable and different independent variables was found using Chi-square test of association at 0.001 level of significance. The following methods were used estimate different parameters:

Adult Male Equivalent = 1 Adult Male = 1.4 Adult Females = 2.5 Children (Jacob and Alles 1989).

$$\text{Food Sufficiency} = \frac{\text{Total quantity of grain produced (wheat and rice) from household land/year}}{\text{Total quantity of grain (wheat and rice) consumed by household/year}} \times 100$$

Adult Cattle Units: Adult Cattle Units (ACU) were worked out using Adult Cattle Unit equivalents used by Upadhyaya (1997):

Cow/bullock/horse/mule = 1.00 ACU

Buffalo = 1.30 ACU

Logistic regression model: In the current study many factors, each individually, motivate farmers for tree intensification on the cropland. However, which of the variables and how exactly these variables are important in motivating farmers for tree intensification when all the variables are taken into account simultaneously is not known. This requires knowledge of the key factors that motive farmers for tree intensification. Logistic regression modelling is an important tool in this regard which has been used widely in health sciences where the dependent variable was dichotomous or binary (Tabachnick and Fidel 1996). However, use of this technique in tree intensification in cropland agroforestry is almost non-existent and would be useful to planners and policy makers in devising the proper extension strategies to encourage farmers intensify the tree cultivation on cropland in the form of agroforestry.

Since the dependent variable for the present analysis: Low intensity adopters (farmers with 1-78 trees/ha) and high intensity adopters (farmers with >78 trees/ha) is binary and ordinary least square assumptions do not hold good in such cases and thus a logistic regression analysis was done. Since there was no previous study in agroforestry to help choose the variables for regression analysis, all independent variables which showed highly significant association with tree intensification were initially chosen as independent variables for logistic regression analysis. For exploratory purposes, the logistic regression analysis was done using the enter method. Some of the coefficients had high value but with very large standard errors. If the regression coefficients are large and their standard errors have very high value. This lowers the Wald statistics and therefore there are chances of increasing the type II error (accepting that effect is non-significant when it is significant) (Tabachnick and Fidel 1996). Therefore, instead of Wald statistics, the Forward Likelihood criterion was followed to select best predicting variables as the main aim was to select the best group of predictors. At each step the predictor which contributed most to prediction is added. For the entry of the predictors in the model the default value of 0.05 significance level was adopted. The standardised coefficients of the variables were found by estimating the standardised score for each variable in the model and running the model using these standardised scores. The significance of the constant in each model was determined on the basis of Wald statistics. The model is as specified below:

Logit is defined as natural log of odds and the model can be specified as:

$$Logit = Ln (P/1-P) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ---------- + \beta_k X_k = Z - 1$$

where

P is the probability of the outcome (Y = 1)

β_0 is the intercept term

β_1, β_2, β_3, and β_k are the coefficients associated with independent variables

X_1, X_2, X_3 and X_k are the predictors in the equation

Logit is linear function of independent variables. The probability can also express as:

$$P = P(Y = 1) = \frac{1}{1 + e^{-logit}} = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k)}}$$

$$\text{Similarly } P(Y_i = 0) = 1 - P_i = \frac{1}{1 + e^{(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k)}}$$

(Greenhouse et al 1995)

In the present study, P is the probability (Y> 78 trees/ha) and 1- P is probability of (Y=1-78 trees/ha). The logistic regression analysis was carried out using binary logistic regression technique in SPSS 22.0 software. For the validation of the model, model Chi-square and Hosmer and Lame show goodness-of-fit and cases correctly classified were taken into account. The Nagelkerke's R^2 was used as measure of determination of variation caused by predictors. The importance of various factors (predictors) in the model was judged on the basis of standardised regression coefficients.

The variables used, their abbreviations and coding for logistic regression analysis are given in Table 1.

RESULTS AND DISCUSSION

Effect of individual factors: There was no association between tree intensification and age of head of household, family type and size of the family (Table 2).

However, the education level of the head of the household significantly influenced the tree intensification (Table 2). The proportion of the high intensity adopters increased from 33.3% in illiterate class to 51.4, 61.4 and 74.3% in class 1-5, 6-10 and ≥ 11, respectively (Table 2). The association between tree intensification and number of government employees, primary occupation of household head, land tenure, number of family members working on farm was also non-significant (Table 3). The influence on the area of crop land owned on tree intensification was significantly (Table 4). Surprisingly the proportion high intensity adopters decreased from 90.3% in marginal farmers to 52.2, 45.8, 47.3 and 38.5% in small, semi-medium, medium and large farmers respectively (Table 4). Welker et al. (2016) also reported a decrease in density of trees with increase in farm size in Kenya.

Crop diversification did not have any association with tree intensification (Table 5). But cropping intensity was also found to have significant association with cropland tree intensification (Table 5). High intensity adopters showed a general increasing trend with crop diversification. The proportion of high intensity adopters increased from 20.8% on cropland with low cropping intensity to 24.4 51.4 and 62.4% on cropland with medium, high and very high cropping intensity. The household food self-sufficiency also had significant association with tree intensification). The proportion of high intensity adopters increased from low food self-sufficiency households to high food self-sufficiency. However, the households with no food self-sufficiency had 100% high intensity adopters. It implies crop intensifiers were also intensifiers of tree cultivation. Further, according to the theory of livelihood strategy food security is an important household livelihood objective. Therefore food deficient households minimised the risk to their food security either by not adopting agroforestry or limiting its extent to avoid reduction in crop yield owing to presence of trees.

The off-farm income did not have any association with tree intensification (Table 6). However, the sale of tree produce had significant association with tree intensification. The proportion of high intensity adopters were higher (66.2%) in households who sold tree produce than who did not sell (40.3%). The level of restrictions on grazing after crop also significantly influence

Table 1. Variable used, their abbreviations and coding for regression analysis

Name of variable	Abbreviation	Coding
Education level of head of household	Edulevel	0=Illiterate, 1=1-5 years, 2=6-10 years, 3=11 years and above
Cropping intensity (%)	Crpint	1=<150, 2=150-170, 3=170-195, 4=195 and higher
Household food sufficiency	Hfss	0=Nil, 1=Low, 2= Medium, 3= High
Household livestock holding (ACUs)	Hlsh	0= No cattle, 1=0.3-2.0, 2=2.0-4.0, 3=4 and above
Quanity of tree produce sold	Qtps	0= Do not sell, 1= Sell
Level of restriction on grazing on cropland after harvest	Resgraz	0= No restriction, 1= Restricted grazing, 3= No grazing
Area under cropland	Acropland	1= Marginal, 2= Small, 3= Semi-medium, 4= Medium, 5= Large

Table 2. Association between tree intensification and age of head of household, family type and size of family

Count % of Row % of Col	Age (Years)		
	Young (23-40)	Middle aged (40-60)	Old (60 or above)
Low Intensity adopters	30	75	65
	17.6	44.1	38.2
	0.4	30.4	
High intensity adopters	40	86	45
	23.4	50.3	26.3
	57.1	53.4	40.9
Total	70	161	110
% of Row	20.5	47.2	32.3

Chi-square= 5.814, D.F.= 2, p< 0.055, CFLF (Cells with frequency less than five)= 0

Association between tree intensification and family type

Count % of Row % of Col	Family type	
	Nuclear	Joint
Low Intensity adopters	98	72
	57.6	42.4
	45.0	58.5
High intensity adopters	120	51
	70.2	29.8
	55.0	41.5
Total	218	123
% of Row	63.9	36.1

Chi-square= 5.803, D.F.= 1, p<0.016, CFLF= 0

Association between tree intensification and size of the family

Count % of Row % of Col	Family size		
	Small (1-3 members)	Medium (4-7 members)	Large (8 members and above)
Low Intensity adopters	36	107	207
	21.2	62.9	15.9
	40.0	51.0	65.9
High intensity adopters	54	103	14
	31.6	60.2	8.2
	60.0	49.0	34.1
Total	90	210	41
% of Row	26.4	61.6	12.0

Chi-square= 7.795, D.F.= 2, p< 0.020, CFLF= 0

Association between tree intensification and education level of head of household

Count % of Row % of Col	Education level (Years of formal education)			
	0 (Illiterate)	1-5	6-10	11 and above
Low Intensity adopters	86	34	41	9
	50.6	20.0	24.1	5.3
	66.7	48.6	38.3	25.7
High intensity adopters	43	36	66	26
	25.1	21.1	38.6	15.2
	33.3	51.4	61.7	74.3
Total	129	70	107	35
% of Row	37.8	20.5	31.4	10.3

Chi-square= 28.486, D.F.= 3, p< 0.0001, CFLF= 0 tree intensification in cropland agroforestry. The proportion of high intensity adopters increased from 13.6% on cropland with free grazing after crop harvest to 44.4 and 78.7% in those with restricted and no grazing respectively. This is in contrast to study in the Philippines where grazing had a positive influence on tree growing (*Samanea saman*) through dissemination of indigestible seeds through animal waste (Pasicolon et al 1997). The intensification with restriction of grazing in the

Table 3. Association between tree intensification and number of government employees, primary occupation of household head, land tenure and number of family members working on farm

Count % of Row % of Col	Number of government employees	
	Do not possess	Possess
Low Intensity adopters	121 71.2 53.1	49 28.8 43.4
High intensity adopters	107 62.6 46.9	64 37.4 56.6
Total % of Row	228 66.9	113 33.1

Chi-square= 2.848, D.F.=1, p<0.091, CFLF= 0

Association between tree intensification and primary occupation of household head

Count % of Row % of Col	Primary occupation	
	Agriculture	Non-agricultural
Low Intensity adopters	100 58.8 58.5	70 41.2 41.2
High intensity adopters	71 41.5 41.5	100 58.5 58.5
Total % of Row	171 50.1	170 49.9

Chi-square=10.209, D.F.=1, p<0.001, CFLF= 0

Association between tree intensification and land tenure

Count % of Row % of Col	Land tenure	
	Share cropping	Self Cropping
Low Intensity adopters	18 10.6 54.5	152 89.4 49.4
High intensity adopters	15 8.8 45.5	156 91.2 50.6
Total % of Row	33 9.7	308 90.3

Chi-square=0.322 D.F.=1, p<0.571, CFLF= 0

Association between tree intensification and number of family members working on the farm

Count % of Row % of Col	Number of family members working on the farm (AME)		
	1-1.5	1.5-3.0	3.0 and above
Low Intensity adopters	25 14.7 32.9	94 55.3 53.4	51 30.0 57.3
High intensity adopters	51 29.8 67.1	82 48.0 46.6	38 22.2 42.7
Total % of Row	76 22.3	176 51.6	89 26.1

Chi-square=11.609, D.F.=2 , p<0.003, CFLF= 0

Table 4. Association between tree intensification and area of agricultural land owned

Count	Agricultural land owned (ha)				
	0.008-0.125 Marginal	0.126-0.250 Small	0.251-0.500 Semi-medium	0.501-1.00 Medium	1.01 and above Large
Low Intensity adopters	3 1.8 9.7	33 19.4 47.8	45 26.5 54.2	49 28.8 52.7	40 23.5 61.5
High intensity adopters	28 16.4 90.3	36 21.1 52.2	38 22.2 45.8	44 25.7 47.3	25 14.6 38.5
Total % of Row	31 9.1	69 20.2	83 24.3	93 27.3	65 19.1

Chi-square=24.610 , D.F.=4, p< 0.0001, CFLF= 0

Table 5. Association between tree intensification and crop diversification, cropping intensity and food sufficiency

Association between tree intensification and crop diversification

Count % of Row % of Col	Crop diversification (Number of crops grown/year)		
	2-4	5-6	7 and above
Low Intensity adopters	76 44.7 50.7	77 45.3 56.2	17 10.0 31.5
High intensity adopters	74 43.3 49.3	60 35.1 43.8	37 21.6 68.5
Total % of Row	150 44.0	137 40.2	54 15.8

Chi-square=9.541 D.F.=2 , p<0.008 CFLF= 0

Association between tree intensification and cropping intensity

Count % of Row % of Col	Cropping intensity (%)			
	<150 Low	150-170 Medium	170-195 High	195 and higher Very high
Low Intensity adopters	42 24.7 79.2	31 18.2 75.6	18 10.6 48.6	79 46.5 37.6
High intensity adopters	11 6.4 20.8	10 5.8 24.4	19 11.1 51.4	131 76.6 62.4
Total % of Row	53 15.5	41 12.0	37 10.9	210 61.6

Chi-square=41.789, D.F.=3, p<0.0001, CFLF= 0

Association between tree intensification and food self sufficiency

Count % of Row % of Col	Food self-sufficienc\y (%)			
	Nil	1-50 Low	51-100 Medium	100 or above High
Low Intensity adopters	0 0 0	46 27.1 63.9	44 25.9 62.0	80 47.1 41.2
High intensity adopters	4 2.3 100.0	26 15.2 36.1	27 15.8 38.0	114 66.7 58.8
Total % of Row	4 1.2	72 21.1	71 20.8	194 56.9

Chi-square=19.582, D.F.=3, p<0.0001, CFLF= 0 current study might be due to better germination and protection of tree seedlings on cropland with restricted or no grazing.

The livestock holding also significantly influenced the proportion of high intensity adopters (Table 7). This might be attributed to farmers with higher lives stock holding might

Table 6. Association between tree intensification and on-farm income

Association between tree intensification and off-farm income

Count % of Row % of Col	Off-farm income (Rs/year)			
	≤15000	15001-30000	30001-60000	≥60001
Low Intensity adopters	22 12.9 62.9	55 32.4 62.5	45 26.5 48.9	48 28.2 38.1
High intensity adopters	13 7.6 37.1	33 19.3 37.5	47 27.5 51.1	78 45.6 61.9
Total % of Row	35 10.3	88 25.8	92 27.0	126 37.0

Chi-square=14,998, D.F.=3, p<0.002, CFLF= 0

Association between tree intensification and sale of tree produce

Count % of Row % of Col	Sale of tree produce	
	Do not sell	Sell
Low Intensity adopters	126 74.1 59.7	44 25.9 33.8
High intensity adopters	85 49.7 40.3	86 50.3 66.2
Total % of Row	211 61.9	130 38.1

Chi-square=21.533 D.F.=1, p<0.0001, CFLF= 0

Table 7. Association between tree intensification, live stock holding and level of restriction on grazing after crop harvest

Count % of Row % of Col	Livestock holding (Adult Cattle Units-ACUs)			
	No cattle	0.3-2.0	2.0-4	4 and above
Low Intensity adopters	14 8.2 35.9	32 18.8 36.4	40 23.5 49.4	84 49.4 63.2
High intensity adopters	25 14.6 64.1	56 32.7 63.6	41 24.0 50.6	49 28.7 36.8
Total % of Row	39 11.4	88 25.8	81 23.8	133 39.0

Chi-square=18.868, D.F.=3, p<0.001, CFLF= 0

Association between tree intensification and level of restriction on grazing after crop harvest

Count % of Row % of Col	Restriction on grazing after crop harvest		
	No restriction (Free grazing)	Restricted grazing	No grazing
Low Intensity adopters	76 44.7 86.4	65 38.2 55.6	29 17.1 21.3
High intensity adopters	12 7.0 13.6	52 30.4 44.4	107 62.6 78.7
Total % of Row	88 25.8	117 34.3	136 39.9

Chi-square=92.723, D.F.=2 , p<0.0001, CFLF= 0

Table 8. Summary of variables and their significance

Step	Variable In:	Coefficients (β)	EXP (β)	Improvement in -2LL (Chi-square)	df	Significance of change (p)	Standardised coefficients
1	Resgraz	1.466	4.330	100.887	1	< 0.0001	1.171
2	Acropland	-0.666	.514	22.255	1	< 0.0001	-0.824
3	Qfps	0.963	2.620	11.145	1	< 0.0001	0.468
4	Edulevel	0.328	1.388	5.975	1	< 0.0001	0.341
	Constant	-1.739			1	< 0.098	

Table 9. Model summary

Statistic	Value	df	p
Initial –2LL	472.723	-	-
Model –2LL	332.461	-	-
Model Chi-square	140.162	4	<0.0001
Hosmer and Lameshow Chi-square	7.932	8	0.440
Nagelkerke R^2	0.449		
N	341		

have intensified tree cultivation to fulfil the demand of the fodder. The level of restriction on on-farm grazing after crop harvest also had significant association with tree intensification. The proportion of high intensity adopters increased from 13.6% in households with no restriction on grazing to 44.4% in households with restricted grazing and finally to 78.7% in households with no grazing on their cropland.

Logistic regression model: The iteration terminated at stage 4. Table 8 presents the model summary. The model is:

Logit = Z = -1.739+ 1.466Resgraz- 0.666Acropland + 0.963 Qfps + 0.328 Edu level

The model was significant (Model Chi-square= 332.461, p< 0.0001, Table 9) which means that model as a whole was significant in predicting the dependent variable compared to model without any variable (also known as intercept model). The Homer and Lameshow Chi-square was non-significant (Table 9). This means that there was no significant difference between the observed and predicted frequencies of two categories of the dependent variable. Therefore the model provides a good fit in estimating the probabilities of the dependent variable. The Step Chi-square (improvement in -2LL) shows that all the variables in the model were individually significant in predicting the dependent variable (Table 8).

Based on the standardised regression coefficients, restriction on grazing (Resgraz) was the most important variable in estimating the probability of adopting high intensity tree cultivation followed by cropland area (Acropland), quantity of tree produce sold (qtps) and education level of household head (Edulevel) respectively. With one unit increase in restriction on grazing (resgraz), quanity of tree produce sold (qtps) and education level of household head (edulevel), the odds of high intensity adoption increased by a factor 4.333, 2.620 and 1.388 respectively, however, with the increase in area under cropland the odds in favour of high intensity adoption decreased by a factor 0.666 (Table 8).

CONCLUSIONS

Out of the studies factors, six factorsnamely education level of the head of household, cropping intensity, household food sufficiency, household livestock holding, quantity of forest produce sold and level of restrictions on grazing after crop harvest significantly and positively influenced the intensification of tree cultivation. Based on logistic regression model, more emphasis needs to be given to restrict on-farm grazing after crop harvest followed by encouraging linkage of tree products for better marketing so as to increasing the intensity of tree cultivation in cropland agroforestry systems. Model also implies a need to encourage households to obtain better education for improving tree intensification on cropland. The influence of the size of cropland holding had also significant but negatively influence of tree intensification implies small holders are likely to have more intensification than the larger. Therefore, specific efforts need to be made to encourage large holder to intensify tree cultivation. The study implies that socio-economic factors needs to be considered while formulating tree intensification strategies.

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