

ARTICLES

Rental Markets of Tilling Machinery: Its Forms and Determinants of Participation in the Brahmaputra Valley of Assam

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ABSTRACT

Based on a survey of 121 farm households in the Brahmaputra Valley of Assam, the present study finds that the rental markets of tilling machinery are functioning in three forms and they are informal in nature. The participation in such markets is primarily guided by the purpose of extracting more returns from cultivation through mechanisation followed by the requirement to adjust with natural endowment related problems. It is found that the intensity of participation on demand side in rental markets of tilling machinery is determined only by the ownership of tilling implements.

Keywords: Rental markets, Tilling machinery, Assam.

JEL: J43, Q12, Q13, Q16

I

INTRODUCTION

Mechanisation, such as the use of a tractor, power tiller, pump set etc. plays a vital role in raising cropping intensity (Rao, 1972; Agarwal, 1984 and Verma, 2018) and productivity of agriculture (Rao, 1972; Roy and Blase, 1978 and Verma, 2018). In India, the importance of farm mechanisation is increasing more due to consistent increasing population pressure coupled with the inelastic nature of land supply. In fact, farm mechanisation can play a significant role in achieving the target of doubling the farmer's income in India by 2022-23 as compared to the year 2015-16, a target set by the Narendra Modi led union government (Government of India, 2017). However, there are many constraints on farm mechanisation in India. For instance, India's agriculture is characterised by the preponderance of small and fragmented holdings¹ which is a major constraint in use of heavy machinery such as tractor, power tiller etc. because the use of such machinery requires a minimum viable size of landholding. In this context, Vaidyanathan (1986) mentions that the size and pattern of landholding can affect profitability from innovations and their adoption. Vaidyanathan has given the example of irrigation to show that if holdings are small and fragmented, the cost of constructing wells and installing pump sets is higher than

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This paper is the outcome of a Minor Research Project granted by the Centre for Development Studies (CDS), Rajiv Gandhi University, Arunachal Pradesh. The author is grateful to CDS for providing the support.

the returns from it. Moreover, the size of landholding in India is declining which makes the introduction of large-scale farm mechanisation difficult as reported in our Journal (IJAE, Inter-Conference Symposium Volume, 2014). Under these circumstances, rental markets of farm machinery can play a significant role. With the emergence of rental markets for indivisible farm machinery, the small size of landholdings will no longer be a problem in farm mechanisation. In the presence of rental markets, indivisible farm machinery becomes divisible and marketable and thus usable even by the small and marginal group of farmers. Rental markets of farm machinery also help cultivation in some adverse situations. In this regard, Rath (2015) points out,

“The average size of cultivated landholdings in India has significantly declined over time. Today more than three-fourths of the cultivated landholdings in the country are of less than 2 hectares in size and more than half of this is of less than 1 hectare. (The average size of holdings of the small farmers is 0.67 ha or 1.78 acres.) It has become very difficult for most small farmers to maintain even one bullock, not to speak of a pair. They tend to hire the bullocks and ploughs from others for the main tilling work or, increasingly, hire tractors, small or large, for the purpose. The larger farmers use tractors rather than keep bullocks” (Rath, 2015: p.12).

Furthermore, as mentioned by Jodha (1974), the functioning of the rental market of farm machinery can help in minimising the under-utilisation of such machinery by renting out which will also add to the farmer’s income who owns the machinery. This is likely to enhance the extent of farm mechanisation by raising the volume of owner users. There is some evidence of the use of hired agricultural machinery in India (Jodha, 1974; Roy and Blase, 1978; Agarwal, 1984; Das, 2015; Rath, 2015) as well as abroad (Lin, 1995). Although the hiring of tilling machinery is evident, the literature on rental markets of such machinery is rather thin. Das (2015) dealt with the extent of rental markets of tilling and irrigation machinery, its impact on agriculture and the impact of credit on the tilling machinery rental market. However, the issues like forms of rental markets of farm machinery and the determinants of participation are yet to be explored by researchers. Of course, Lin (1995) did identify the determinants of tractor hiring by farmers but without considering the impact of factors like ownership of tilling implements, access to credit, the extent of tenancy, farm size etc. Though Ray (2011) discussed the agricultural factor markets but did not deal specifically with the rental markets of farm machinery while Binswanger and Rosenzweig (1986) had tried explaining the possibility of rental markets of farm machinery and some other agricultural inputs. The present study, therefore, tries addressing the above gaps.

Tilling is a key farming activity and the machinery used for it are costly in nature. Therefore, the present study is confined only to the rental market of tilling machinery. The other costly farm machinery like the pump set and combine harvester are not included in the study as rental markets for them are unlikely to be extensive. It is found that while the mobility of pump set is limited, use of other heavy farm

machinery like the combine harvesters is not so extensive.² Moreover, the other small farm machinery does not require large-scale investment and hence their rental markets may not exist or even if they exist, they are unlikely to be extensive.

With reference to the foregoing discussion, the objectives of the present study are outlined here: (i) To see the forms of rental markets of tilling machinery; (ii) To find out the determinants of participation in such markets

The present study also tries addressing the research question as to whether the participation in rental markets of tilling machinery is only to mechanise the farm operation or also to adjust with the changing environment (i.e., natural endowment related challenges).

Assam is an agriculture-based state in India³ where small and marginal holdings are preponderant.⁴ Given the role of rental markets of farm machinery in mechanised cultivation on the one hand and the characteristics of agriculture in Assam on the other hand, it is felt that the issue under consideration is relevant for the state. Accordingly, the Brahmaputra Valley of the state (which comprises around 72 per cent of the total geographical area of the state) has been taken up as the sample location for the present study.

The rest of the paper has been divided into three sections. Section II explains the data source, the procedure of sample selection and the analytical framework of the study. Section III comprises the results and discussion on the forms of rental markets of farm capital goods and the determinants of participation in it on the basis of primary inputs. The final section of the paper ends with concluding remarks.

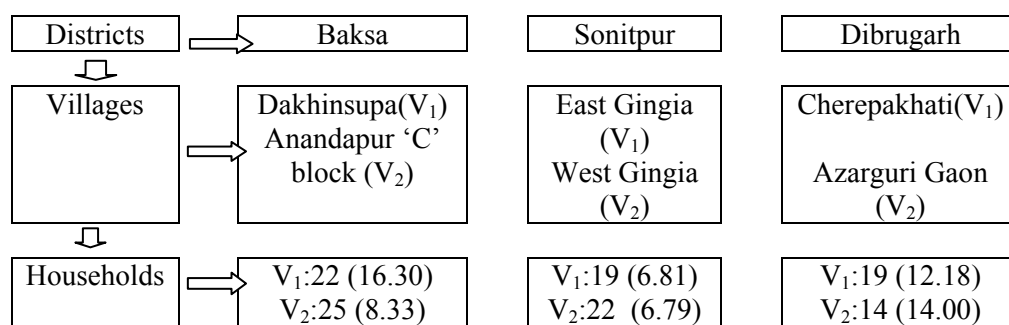
II

METHODOLOGY

2.1 Data Source and Sampling Design

Although secondary information has been used as per requirement, the core of the study is based on field study data. It was during January-February, 2016 that inputs from the field were collected by adopting a multi-stage sampling procedure. As the main purpose of the study is to see the forms and determinants of participation, we tried selecting the districts in the state where rental markets of tilling machinery are likely to be more extensive. Accordingly, using district-level secondary data provided by *Input Survey 2006-07*, Government of India, a total of three districts were selected purposively in the first stage such that the extent of use of tilling machinery in those districts is not the lowest among the districts in the Brahmaputra Valley. Further, the districts were selected in such a way that they represented the different agro-climatic zones making the sample a more representative one. In the second stage, two villages from each district with a total of six villages were chosen at random. Finally, depending on the number of farm households in the villages, from each village 6.79 per cent to 16.30 per cent of the total farm households were surveyed at random as

the eventual sampling units. The total households surveyed for the present study stands at 121 (which constitutes around 9.35 per cent of the total farm households of the surveyed villages). The sampling procedure has been summarised in Chart 1.



Figures in parentheses are percentages of the surveyed households to the total farm households in the villages.

Chart 1. Sampling Procedure.

2.2 Analytical Framework

The forms of rental markets have been identified by looking into the basis of rental rate fixation. Further, it is also explored whether such markets are formal or informal and what is the mode of payment of rental rates.

To fulfil the second objective, first, the purpose of participation in such markets is examined. This also gives the answer to the research question pursued in the study. Subsequently, exclusive hirers (ploughed only by using hired machinery) and partial hirers (other than exclusive hirers) are compared in terms of their socio-economic characteristics. Finally, in order to identify the determinants of participation in rental markets of tilling machinery, we have calculated the intensity of tilling by hired machinery (ITHM) which has been defined as:

$$ITHM = \frac{\sum_{i=1}^n x_i t_i}{\sum_{i=1}^n y_i s_i} \times 100$$

where i represents a crop out of 'n' crops cultivated in the reference year

x_i represents area under i -th crop ploughed by hired machinery

t_i represents the number of rounds ploughed for the area under the i -th crop by hired machinery

y_i represents area under i -th crop ploughed by all implements

s_i represents the number of rounds ploughed for the area under the i -th crop by all implements.

The identification of determinants of participation in rental markets of tilling machinery in terms of ITHM is biased towards demand side as it considers hirers only. But there is no alternative as all the sample farmers in the present study are participants in such markets. Moreover, the ITHM is a better indicator which captures both participation status as well as its intensity than an indicator that captures only

the participation status. Regressing ITHM on expected factors, determinants of participation in rental markets of such machinery have been identified.

For identification of determinants of ITHM, the probable factors have been selected based on field survey experience and review of the literature. As tilling by own inputs is a substitute to the tilling by hired inputs, we can expect that the ownership of tilling inputs, either draft animals or machinery has a negative impact on the ITHM. The dependency on machinery is likely to be more for a large farmer for ease of operation and/or for timely cultivation and hence a positive relationship between ITHM and farm size can be anticipated provided he/she is not an owner of such machinery. The extent of the tenancy may discourage the intensity of tilling by hired machinery as benefits in the form of output needs to be shared with the landlord without sharing the hiring cost. A farmer may rely more on hired machinery for tilling if he/she is subjected to manpower shortage as maintenance and operation of own tilling inputs require human services. Mohamed and Temu (2008) in this regard, mentioned that household size has an adverse impact on the adoption of technology in farm operation provided such households are not credit constrained. By raising awareness about the advantages of farm mechanisation, the level of education may increase the ITHM. Further, Kuri (2003) while discussing the factor markets and its imperfection pointed out that the new generations in farm households are less interested in manual agriculture operation. Owing to the fact that the hiring of tilling machinery requires payment of rent, a positive impact of access to credit on ITHM can be anticipated. In fact, there is evidence of the significant positive impact of institutional credit in the adoption of modern technology in farm operation (Swamy, 1980 and Mohamed and Temu, 2008). However, access to informal credit may play a more significant role than formal credit in the hiring of tilling machinery as money required for payment of rent is a small amount and needed to be paid instantaneously. It is also possible that the sources of livelihoods may affect the intensity of use of hired machinery in cultivation. It is a fact that farmers who are engaged and earn only from own cultivation can devote more time to their cultivation than farmers engaged in work(s) other than their cultivation and hence, the dependency on hired tilling machinery is likely to be less by the former type than the latter type. In contrast, given the fact that farmers, for whom cultivation is the only source of family income, normally goes for more intensive cultivation, therefore, their intensity for mechanisation and hence the ITHM are likely to be high. Hence, *a priori*, it is not possible to expect a specific sign for this variable. The explanatory variables⁵ included in the regression are summarised in Table 1.

Model Specification

Assuming the ITHM as the dependent variable, the regression model has been constructed as follows:

$$\text{ITHM} = F(\text{TM}, \text{DA}, \text{FS}, \text{TEN}, \text{WM}, \text{EDU}_1, \text{EDU}_2, \text{EDU}_3, \text{EDU}_4, \text{NS}, \text{IS}, \text{PC}, \text{L}_1, \text{L}_2)$$

TABLE 1. VARIABLES INCLUDED IN REGRESSION FOR DETERMINANTS OF THE INTENSITY OF TILLING BY HIRED MACHINERY

Variable (1)	Notation (2)	Definition (3)	Expected impact (4)
Ownership of the tilling machinery	TM	It is a dummy variable which takes 1 for owner and 0 otherwise	-
Ownership of the draft animal	DA	It is a dummy variable which takes 1 for owner and 0 otherwise	-
Farm size	FS	It has been measured in terms of the size of operational holding	+
Extent of tenancy	TEN	It has been measured as a ratio of leased-in land to the operational land	-
Size of working members	WM	It is the number of working members in a household	-
Education of head of the household	EDU ₁ EDU ₂ EDU ₃ EDU ₄	EDU ₁ =1 for below primary, 0 otherwise, EDU ₂ =1 for primary to high school, 0 otherwise, EDU ₃ =1 for matriculation to undergraduate, 0 otherwise and EDU ₄ =1 for graduate and above, 0 otherwise assuming illiterate as the base category	+
Access to credit ⁶	NS	NS is a dummy which takes 1 if money borrowed from non-institutional sources and 0 otherwise	+
	IS	IS is a dummy which takes 1 if money borrowed from institutional sources and 0 otherwise assuming non-borrowers as the base category	
Pure cultivator	PC	It is a dummy which takes 1 for the household earning only from own cultivation and 0 otherwise.	+/-
Location characteristics	L ₁ & L ₂	L ₁ =1 for Baksa and 0 otherwise. L ₂ = 1 for Sonitpur and 0 otherwise assuming Dibrugarh as the reference location	+/-

As the range of the dependent variable is 0 to 100, linear regression will not be suitable. We have also clusters of 7 observations at 0 and 61 observations at 100. Hence, both sides censored TOBIT regression has been formulated as follows:

$$ITHM_i^* = \beta_0 + \beta_1 TM_i + \beta_2 DA_i + \beta_3 FS_i + \beta_4 TEN_i + \beta_5 WM_i + \beta_6 EDU_{1i} + \beta_7 EDU_{2i} + \beta_8 EDU_{3i} + \beta_9 EDU_{4i} + \beta_{10} NS_i + \beta_{11} IS_i + \beta_{12} PC_i + \beta_{13} L_{1i} + \beta_{14} L_{2i} + U_i$$

where $ITHM_i = 100$ for $ITHM_i^*$ greater than 100
 $= ITHM_i^*$ for $0 \leq ITHM_i^* \leq 100$
 $= 0$ for $ITHM_i^*$ less than 0
and U_i s are the usual disturbance terms.

III

RESULTS AND DISCUSSION

3.1 *Forms of Rental Markets*

The rental markets of tilling machinery are extensive in surveyed locations.⁷ On the basis of rental rate fixation, these markets are functioning in three forms— hourly-based, daily-based and area-based (Table 2). However, it is only in the Sonitpur district that the rental markets of tilling machinery are functioning in three forms, while in Baksa and Dibrugarh districts, such markets are functioning only in area-based form. As per our data set, the area-based form of the rental market is more widespread in terms of household participation and the rounds of hiring, while in terms of area ploughed, the daily-based form is dominant. Across machinery, rental markets of both tilling tractors and tilling-cum-levelling tractors are functioning in all the three forms. The rental market of power tillers is functioning only in area-based form. Further, the rental markets of tilling machinery are completely informal in nature and cash is the only mode of payment.

TABLE 2. TYPES OF HIRING OF TILLING MACHINERY

Machinery (1)		Time-based			Area-based (in Bigha ⁸) (6)	Grand total (7)
		Daily (3)	Hourly (4)	Total (5)		
TT	H	021(27.27)	019(24.68)	036(46.75)	041(53.25)	077(100)
	R	186(30.39)	141(23.04)	327(53.43)	285(46.57)	612(100)
	A	944.45(59.88)	388.42(24.63)	1332.87(84.51)	244.33(15.49)	1577.20(100)
TLT	H	003(03.95)	033(43.42)	036(47.37)	040(52.63)	076(100)
	R	008(02.06)	138(35.57)	146(37.63)	242(62.37)	388(100)
	A	40.16(06.10)	498.06(75.70)	538.22(81.81)	119.68(18.19)	657.90(100)
PT	H	000(00.00)	000(00.00)	000(00.00)	026(100.00)	026(100)
	R	000(00.00)	000(00.00)	000(00.00)	066(100.00)	066(100)
	A	000(00.00)	000(00.00)	000(00.00)	76.64(100.00)	76.64(100)
TM	H	021(18.42)	033(28.95)	038(33.33)	078(68.42)	114(100)
	R	194(18.20)	279(26.17)	473(44.37)	593(55.63)	1066(100)
	A	984.61(42.59)	886.48(38.35)	1871.09(80.94)	440.65(19.06)	2311.74(100)

Figures in parentheses indicate percentage to the grand total.

TT- Tilling tractor, TLT-Tilling-cum-leveller tractor, PT- Power tiller, TM- Tilling machinery, H-Household, R-Round & A-Area (in hectare) considering the round of tilling

While 94 per cent of the sample households have tilled their cropped land using hired machinery, the overall intensity of tilling by such machinery is 67 per cent as depicted by Figure 1. Across crops, the value of ITHM⁹ is not the same which ranges from 59 to 100 per cent.¹⁰ However, pulses, for which ITHM is the highest, is found to be cultivated by only one sample household. It is observed that the ITHM for cultivating *rabi* crops like rapeseed and mustard, pulses, potato and winter vegetables are above the overall ITHM. In contrast, the ITHM for growing of *kharif* crops like winter and autumn rice are below the overall ITHM; although it is not so in case of

the summer vegetables. Thus, ITHM during *rabi* is higher than that of *kharif* season. This is because of the fact that during *kharif* season precipitation enhances moisture of soil which, in turn, requires fewer rounds of tilling by machinery compared to *rabi* season.

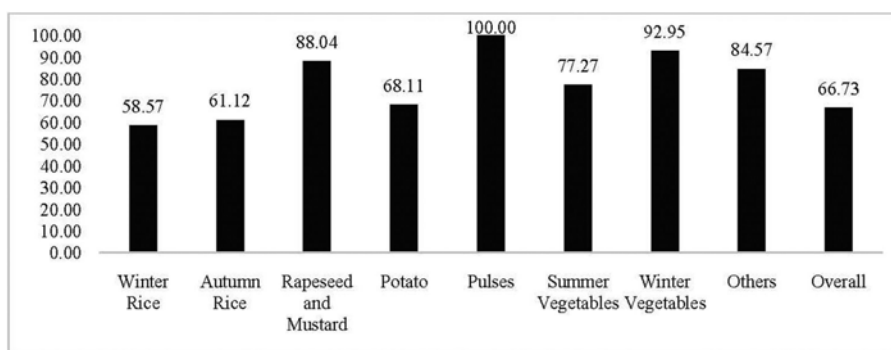


Figure 1. Intensity of Tilling by Hired Machinery (in per cent)

The rental rates¹¹ for different tilling machinery are not the same (Table 3). Tilling-cum-leveller tractors are most expensive in terms of the rental rate across all the forms of rental markets. However, rental rate of both tilling cum leveller tractors and power tillers are the same across the area-based rental markets. The higher rental rate of tilling cum levelling tractors over tilling tractors is mainly because the former is used to plough and level the land simultaneously while the latter is used only to plough the land. Across locations too, rental rates of tilling tractors and power tillers varies. Rental rate of tilling tractors is highest in Sonitpur district and lowest in Baksa district. However, in Sonitpur district only one household is found to have hired tilling tractor under the area-based form. In the case of power tiller, rental rate is the highest in Baksa and lowest in Dibrugarh district.

TABLE 3. AVERAGE RENTAL RATES ACROSS LOCATIONS

Location (1)	(Rs.)						
	Per Bigha/round			Per day		Per hour	
	TT (2)	TLT (3)	PT (4)	TT (5)	TLT (6)	TT (7)	TLT (8)
Baksa	197	290	302	NA	NA	NA	NA
Sonitpur	400	NA	300	2531	3867	413	586
Dibrugarh	206	NA	281	NA	NA	NA	NA
Overall	207	290	290	2531	3867	413	586

3.2 Factors Affecting Rental Market Participation

3.2.1 Purpose of Participation

Among the participants in rental markets of tilling machinery, mechanisation of agriculture is found to be the prime motive of participation both on demand and

supply side. Of course, a significant proportion of participants' purpose of participation in such markets is to deal with the changing environment like maintenance difficulty due to the reduction of grazing land, frequent flood etc. The higher cost of tilling inputs, lack of manpower, engagement in non-farm activities, the small size of landholdings etc. also have encouraged some farmers to participate in such markets. However, most of the participants have multiple purposes for participation.

TABLE 4. DISTRIBUTION OF MARKET PARTICIPANTS BY PURPOSE (MAIN) OF PARTICIPATION

Purpose (1)	Demanders ¹² (2)	Supplier ¹³ (3)
To increase return from agriculture through mechanisation ¹⁴	77 (67.54)	14 (77.78)
To adjust to the changing environment	25 (21.93)	04 (22.22)
To earn return from investment ¹⁵	NA	00 (00.00)
Others	12 (10.53)	00 (00.00)
Total	114 (100.00)	18 (100.00)

Figures in parentheses indicate percentage to the total participants.

NA-Not Applicable.

3.2.2 Characteristics of Participants

While all the sample farm households are found to participate in the rental markets of tilling machinery, 94 per cent of them is found to have participated on demand side and only 15 per cent of them participated as suppliers.¹⁶ Moreover, it has not been possible to get the intensity of renting of tilling machinery by the suppliers. Hence, the discussion in the present section focuses on demanders. In terms of the intensity of hiring, a total of 54 per cent of the hirers (which constitute 50 per cent of sample households) are found to be exclusive hirers and the rest 46 per cent are partial hirers. Thus, the majority of sample households and thus market participants are exclusively dependent on hired tilling machinery for carrying out their tilling operation. As the intensity of tilling machinery is not same across farmers, an attempt has been made here to compare the partial and exclusive hirers in terms of their socio-economic characteristics.

Table 5 depicts that the exclusive hirers are small farmers as compared to the partial hirers both in terms of operational holdings as well as ownership holdings of cultivable land which is against the general perception. However, this could be because (a) as exclusive hiring-in farmers have land of smaller size; they may feel that tilling completely by hired machinery is less expensive and more convenient than by own tilling inputs as their requirement is less, and (b) generally farm size and economic condition of the farmers goes in the same direction. Thus, smaller is the size of landholding of farmers, more is the financial constraint and hence they prefer to plough by hired machinery rather than owning them.

TABLE 5. SIZE OF HOLDINGS BY TYPES OF HIRING HOUSEHOLDS

Types of hirer (1)	<i>(area ha)</i>	
	Operational holdings (2)	Ownership holdings of cultivable land (3)
Exclusive hirers	2.57	1.07
Partial hirers	2.94	1.08
Total hirers ¹⁷	2.74	1.07
Non-hirers	5.50	3.24
Overall HH	2.90	1.20

In terms of educational attainment of the head of the households, a larger number of exclusive hirers have education up to matriculation and above than the partial hirers. A total of 49 per cent of the exclusive hirers are matriculated and above while it is only 25 per cent in case of the partial hirers (Table 6). Thus, for farmers who are matriculates and above, the dependency on hired machinery is more which is at least to some extent due to the fact that proportionately a sizable percentage of them are engaged in non-farm activities.¹⁸

TABLE 6. PERCENTAGE DISTRIBUTION OF HIRING HOUSEHOLDS BY EDUCATIONAL ATTAINMENT

Types of hirers (1)	Not literate (2)	Below primary (3)	Primary to high school (4)	Matriculate to undergraduate (5)	Graduate and above (6)	Overall (7)
Exclusive hirers	8.20	3.28	39.34	42.62	06.56	100.00
Partial hirers	15.09	3.77	56.60	18.87	05.66	100.00
Total hirers	11.40	3.51	47.37	31.58	06.14	100.00
Non-hirers	14.29	0.00	14.29	57.14	14.29	100.00
Overall HH	11.57	3.31	45.45	33.06	06.61	100.00

Table 7 depicts that 44 per cent of the tilling machinery hirers are pure farmers (those households earning only from own agriculture) while 56 per cent are mixed-income farmers (farm households other than pure cultivators). Further, the proportion of mixed-income farmers among exclusive hirers is even more than among partial hirers. It implies that the engagement of farmers in other activities other than agriculture increases the extent of dependency on hired tilling machinery.

TABLE 7. PERCENTAGE DISTRIBUTION OF HIRING HOUSEHOLDS BY TYPES OF OCCUPATION

Types of hirers (1)	Pure cultivator (2)	Others (3)	Total (4)
Exclusive hirers	42.62	57.38	100.00
Partial hirers	45.28	54.72	100.00
Total hirers	43.86	56.14	100.00
Non-hirers	71.43	28.57	100.00
Overall HH	45.45	54.55	100.00

As per our data set, the exclusive hirers are found to have a lesser number of working family members than the partial hirers (Table 8). It shows that scarcity of manpower raises the dependency on hired tilling machinery which can be due to maintenance and operational difficulty of having own tilling equipment.

TABLE 8. SIZE OF WORKFORCE

Types of hirers (1)	Average size (2)
Exclusive hirers	1.89
Partial hirers	2.19
Total hirers	2.03
Non-hirers	2.00
Overall HH	2.02

3.2.3 Determinants of the Intensity of Tilling by Hired Machinery

Table 9 shows that on an average the farm size of the sample farm households stands at 2.90 hectares and it ranges from 0.13 hectare to 24.10 hectares. The sample comprises both pure tenants and owner-operators. The extent of tenancy is 42 per cent. The maximum number of working members of the sample farm households is five and the minimum is one. A total of 17 per cent of the sample households owns tilling machinery and 30 per cent owns draft animals. Most farmers fall in the educational attainment group of primary to high school. The sample comprises 27 per cent institutional borrowers and 31 per cent non-institutional borrowers.

TABLE 9. DESCRIPTIVE STATISTICS OF EXPLANATORY VARIABLES

Non-categorical variables (1)	Mean (2)	S. D. (3)	Min (4)	Max (5)
FS (size of operational holding in hectare)	2.90	3.61	0.13	24.10
TEN (ratio of leased-in area to the operational holding)	0.42	0.40	0	1
WM (number of working members in a household)	2.03	1.05	1	5
Dummy variables	Percentage			
TM (1 for an owner of tilling machinery, 0 otherwise)	16.53			
DA (1 for an owner of the draught animal, 0 otherwise)	29.75			
EDU ₁ (1 for below primary, 0 otherwise)	03.31			
EDU ₂ (1 for primary to high school, 0 otherwise)	45.45			
EDU ₃ (1 for matriculation to undergraduate, 0 otherwise)	33.06			
EDU ₄ (1 for graduate and above, 0 otherwise)	06.61			
NS (1 for borrowers from non-institutional sources, 0 otherwise)	31.40			
IS (1 for borrowers from institutional sources, 0 otherwise)	27.27			
PC (1 for households earning only from own cultivation, 0 otherwise)	45.45			
Baksa	38.84			
Sonitpur	33.88			

Maximum likelihood estimates of parameters have been obtained using STATA.13. The results show that variables TM and DA are statistically significant at one per cent with negative coefficients. It implies that the ownership of tilling machinery and draft animals reduce the intensity of tilling by hired machinery which is quite natural. Use of tilling machinery by hiring is a substitute for the use of own tilling inputs. Other variables like FS, TEN, WM, EDU₁, EDU₂, EDU₃, EDU₄, NS, IS and PC are found to be insignificant. It implies that these factors have no significant impact on the intensity of the hiring of tilling machinery. The insignificance of

location dummies reveals the absence of impact of location-specific factors on the intensity of tilling by hired machinery.

TABLE 10. REGRESSION RESULTS

Variables	Breusch-Pagan test for heteroskedasticity		
	chi ² (1) = 12.06 Prob > chi ² = 0.0005		
	Coefficient	Robust S.E.	p-value
(1)	(2)	(3)	(4)
TM	-100.660***	12.662	0.000
DA	-67.686***	7.999	0.000
FS	1.679	1.382	0.227
TEN	-1.220	10.122	0.904
WM	-0.759	3.752	0.840
EDU ₁	0.619	14.716	0.967
EDU ₂	1.332	11.058	0.904
EDU ₃	-0.949	12.517	0.940
EDU ₄	8.900	19.065	0.642
NS	8.290	9.498	0.385
IS	-9.127	7.553	0.230
PC	-0.107	6.348	0.987
Baksa(L ₁)	-1.330	8.689	0.879
Sonitpur(L ₂)	-1.319	10.905	0.904
Constant	128.591***	16.591	0.000
F	10.27 (14, 107)***		
Pseudo R ²	0.1872		
VIF	The individual maximum is 3.02 and average is 1.89		

Figures in parentheses represents degrees of freedom.

*** represents significance at one per cent level.

The regression results depict that apart from TM and DA, other explanatory variables are insignificant in determining the intensity of tilling by hired machinery. With the aim to check whether any explanatory variable is redundant, we have estimated six other regressions dropping one insignificant explanatory variable each time. However, dropping of insignificant explanatory variables has not resulted in any improvement of pseudo R² (Appendix A1). Thus, none of the insignificant explanatory variables is found to be redundant.

IV

CONCLUSION

Rental markets of tilling machinery are informal in nature and they are functioning in three forms in the study area. The area-based form is the common one among the three forms of rental markets of tilling machinery. Participation in the rental markets of tilling machinery is mainly motivated by the realisation of benefits of agricultural modernisation in terms of tilling mechanisation. However, a significant proportion of the farmers also primarily depend on hired tilling machinery to avoid the maintenance difficulty of draft animals as pointed out by Rath (2015).

Therefore, the farmers participate in rental markets of tilling machinery not only to mechanise their farm operation but also to adjust with the changing environment.

It is found that the participation of farm households in rental markets of tilling machinery is predominantly on the demand side (hirer). Further, the intensity of hiring of the tilling machinery of farmers is determined by the ownership of both draft animals and tilling machinery. The ownership of draft animals and tilling machinery reduces the intensity of hiring of tilling machinery. Given that the participation of farm households in rental markets of tilling machinery is large as hirers and their intensity of hiring of tilling machinery rely on the ownership of draft animals and tilling machinery, it can be concluded that ownership of tilling implements determines the participation of farmers in such markets to a great extent.

Received February 2017.

Revision accepted March 2019.

NOTES

1) Around 85 per cent of the operational holdings are small and marginal with the average size being 1.15 hectare (*Agriculture Census*, Government of India, 2010-11).

2) As per Input Survey, 2011-12, Government of India, the percentage of operational holdings using combine harvester (tractor powered) and combine harvester (self-propelled) are 2.02 per cent and 1.38 per cent respectively in the country.

3) Agriculture, forestry and fishing account for 20 per cent of the gross state value added at constant (2011-12) prices in 2016-17 (QE) (*Economic Survey*, Assam, 2017-18) and 56 per cent of workers according to Usual Status (PS+SS) are engaged therein (Key Indicators of Employment and Unemployment in India, NSS 68th Round, 2011-2012, Government of India).

4) As per *Report on Agricultural Census 2010-11* on Number and Area of Operational Holdings (Phase-I), Government of Assam, around 86 per cent of the operational holdings are small and marginal and the average size of operational holdings is 1.10 hectare.

5) The tilling machinery used in survey locations are - power tiller, tractor use for ploughing and tractor use for ploughing and levelling simultaneously. Depending on the types of tilling machinery, rental rates are different. Moreover, some farm households have used more than one types of tilling machinery. Further, rental rates are fixed in three forms- per bigha, per day and per hour. Hence, in the regression analysis, it was not possible to use the rental rate as a potential determinant of participation in the rental market.

6) If a household borrows money from both institutional and non-institutional sources, such a household has been treated as an institutional borrower as they avail the same advantages as the pure institutional borrower.

7) All the sample households participated in the rental market of tilling machinery as a whole. Individually, the percentages of sample households who participated in rental markets of the tilling tractor, tilling cum leveler tractor and power tillers are 66.94 percent, 65.29 percent and 29.75 percent respectively whereas only 8.26 percent of the sample households participated in the draft animal rental.

8) Bigha is a common unit of land measurement used in Assam and one Bigha is equal to 0.13387 hectare.

9) The intensity of tilling by hired machinery for individual crops is defined as: $\frac{x_i t_i}{y_i s_i}$

Where, x_i denotes area under i -th crop ploughed by hired machinery, t_i represents the number of rounds area under crop ' i ' is ploughed by hired machinery, y_i denotes area under i -th crop ploughed by all implements, s_i denotes the number of rounds under crop ' i ' ploughed by all implements

10) Cultivation of summer rice was not reported by sample households.

11) Rental rates include fuel cost.

12) Any household hiring tilling machinery

13) Any household giving tilling machinery on rent.

14) For demanders, it means increase of return from agriculture due to mechanisation while for suppliers, it means that the suppliers have purchased such machinery mainly to use them in their own land to raise their return from cultivation and rent out such machinery only when they are not in use in their own land.

- 15) It means that the main purpose of purchasing such machinery is to earn revenue by renting them out rather than to use them in their own cultivation.
- 16) The sum of percentages of demanders and suppliers is more than 100 per cent as seven sample households participated both as demander and supplier whom we have included in both demand and supply sides.
- 17) Total hirers include both exclusive and partial hirers.
- 18) The average level of educational attainment of the sample pure farmers is 7.31 years and for the other farmers, it is 8.45 years.

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APPENDIX A1
RESULTS OF REDUNDANCY TEST

	Model 1#	Model 2	Model3	Model 4	Model 5	Model 6	Model 7
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
(1)	(RSE)	(RSE)	(RSE)	(RSE)	(RSE)	(RSE)	(RSE)
	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TM	-100.660 (12.662)***	-100.676 (12.906)***	-103.672 (12.702)***	-100.269 (13.102)***	-101.106 (12.584)***	-100.667 (12.649)***	-94.492 (11.799)***
DA	-67.686 (7.999)***	-67.690 (8.052)***	-68.460 (7.795)***	-66.899 (7.734)***	-67.863 (8.010)***	-67.710 (7.981)***	-66.414 (8.123)***
FS	1.679 (1.382)	1.680 (1.393)	1.769 (1.488)	1.691 (1.310)	1.680 (1.385)	1.654 (1.344)	--
TEN	-1.220 (10.122)	-1.260 (10.032)	0.455 (11.215)	-2.688 (9.410)	-1.066 (10.076)	--	1.346 (9.913)
WM	-0.759 (3.752)	-0.739 (3.630)	0.088 (3.775)	-0.553 (3.621)	--	-0.731 (3.741)	-0.736 (3.688)
EDU1	0.619 (14.716)	0.594 (14.630)	-7.063 (15.459)	--	0.840 (14.604)	0.714 (14.616)	2.785 (14.889)
EDU2	1.332 (11.058)	1.324 (11.051)	-0.951 (11.343)	--	1.388 (11.033)	1.528 (10.365)	4.206 (10.830)
EDU3	-0.949 (12.517)	-0.942 (12.454)	-3.878 (12.333)	--	-0.659 (12.223)	-0.766 (12.030)	1.864 (12.278)
EDU4	8.900 (19.065)	8.922 (18.943)	2.122 (19.885)	--	8.924 (18.879)	9.400 (18.223)	11.433 (18.779)
NS	8.290 (9.498)	8.286 (9.523)	--	8.111 (8.999)	8.195 (9.418)	8.031 (10.180)	11.006 (9.782)
IS	-9.127 (7.553)	-9.137 (7.613)	--	-8.402 (7.490)	-8.983 (7.597)	-9.240 (7.495)	-7.549 (7.546)
PC	-0.107 (6.348)	--	-1.079 (7.061)	-0.429 (6.011)	0.666 (6.493)	-0.385 (6.413)	-0.695 (6.613)
Baksa (L ₁)	-1.330 (8.689)	-1.328 (8.705)	-2.379 (8.859)	-2.224 (8.736)	-1.481 (8.597)	-1.217 (8.755)	-2.368 (8.514)
Sonitpur (L ₂)	-1.319 (10.905)	-1.309 (10.934)	2.572 (10.656)	-1.168 (10.727)	-1.157 (10.929)	-1.372 (10.752)	3.875 (10.868)
Constant	128.591 (16.591)***	128.522 (15.812)***	129.056 (16.238)***	129.674 (10.102)***	126.660 (14.625)	128.110 (15.586)	126.184 (16.382)
F	10.27 [14,107]***	10.24 [13,108]*	10.77 [12,109]***	12.64 [10,111]***	10.93 [13,108]***	10.71 [13,108]***	10.10 [13,108]***
Pseudo R ²	0.1872	0.1872	0.1830	0.1867	0.1872	0.1872	0.1849

Figures in () and [] are Robust Standard Errors and degrees of freedom respectively.

*** represents significance at one per cent level.

#Model 1 is the baseline regression model considered for the present analysis.