Agricultural Economics Research Review 2022, 35 (Conference Number), 145-163
DOI: 10.5958/0974-0279.2022.00027.1

Choice of millets cultivation in India: an evidence from farm household survey data

Umanath Malaiarasan[1]*, R Paramasivam[2], and V Saravanakumar[3]

[1]Madras Institute of Development Studies, Chennai, Tamil Nadu 600 020, India
[2]Kumaraguru Institute of Agriculture, Erode, Tamil Nadu 638 315, India
[3]Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu 641 003, India

*Corresponding author: umanatheconomics@gmail.com

Abstract The present study aims at investigating the determinants of millets production at the farm-household level in India. We have used farm household survey data collected by the National Sample Survey for the year 2018-19. Using Heckman sample selection model, the study has estimated the functional relationship between area adoption under millets and various farm household-related characteristics to avoid the sample selection problem associated with the survey data. The results reveal that the price of millets is the key factor affecting the choice of millets production and area expansion. Ensuring a higher price for millets may encourage the expansion of area under millets. As millets are considered less input intensive crops and rich in nutrients, more area adoption under millets may help achieve the sustainable development goals of food security and efficient use of resources.

Keywords Nutrient security, millets, probability, sample selection, adoption

JEL codes Q12, Q13, Q15, Q16

Introduction

Millets contain high nutritive values such as proteins, minerals, vitamins, antioxidants, non-glutinous and non-acid forming diets, as compared to other cereals. They are called as 'nutritious millets' or 'nutricereals' and they, therefore, are considered more for human consumption. Bajra (pearl millet) and ragi (finger millet), among other millets, possess protein content of 11.8 and 7.4 g per 100 gram grain, respectively and low fat of around 1.3 g per 100 g grain (Sakamoto 1982; Muthamilarasan et al. 2016). Moreover, millets have higher levels of low Glycemic Index (GI) non-starch polysaccharides and dietary fibres protecting against diabetes. Most of the millet crops are cultivated in the semi-arid regions as they are resilient to climate change; require low labour, water, inorganic fertilizers and other market inputs; resistance to pests and diseases; require a short duration (60-90 days); and survive under low rainfall, high temperatures, and poor nutrient levels in the soil (Lata et al. 2013; Bergamini et al. 2013). Further, the cultivation of millets can contribute to carbon sequestration and reduction in greenhouse gas emissions. However, the area under millet crops and their production shows a significantly declined trend over the decades.

The decline in the millet production could be attributed to a less demand and over-dependency on rice and wheat accounting for about 50% of the average Indian household calorie intake and significant changes in the dietary pattern of households from cereals to high-value food commodities such as livestock products, fruits, vegetables and beverages (Bansil 1999; Radhakrishna 2005; Chatterjee et al. 2006; Chandrakanth and Akarsha 2011; Kumar et al. 2011). Besides, an increase in per capita income, growing urbanisation, availability of expected fresh and processed food products in the market, improvements in transportation, storage facilities and a rise in supermarkets and changing tastes

and preferences are some of the other factors responsible for a decline in the production and consumption of millets (Chand 2007; Chengappa et al. 2007; Kumar et al. 2011; Vasileska and Rechkoska 2012). Also, a less attention paid by researchers with respect to the significance of underutilized millets (Padulosi and Hoeschle-Zeledon 2004), resulted in neglected nutrition and health opportunities (Frison et al. 2006; Hawtin 2007; Smith and Longvah 2009). On the other side, limited marketing opportunities available to these so-called inferior millets are also responsible for their low-price levels, and affecting the producers (Nagarajan et al. 2005).

Although a couple of studies have dealt with the importance of millets in terms of demand and performance by the public (Anbukkani et al. 2017; Umanath et al. 2018), a detailed information on the nature of production choice and area expansion at the farm level is unavailable. Such information is needed for producers, market actors to take market-oriented production decisions in order to benefit from growing markets (Lapar et al. 2010) and policy makers to initiate millets production promotion strategies as these crops consume a low amount of water and chemicals besides being climate resilient in nature. Given their importance in respect of farm production decisions, it is crucial for policy makers and other stakeholders involved in the production, marketing and processing of millets to understand the factors determining the production choice of millets and adoption at the farm household level.

A number of previous studies have estimated the adoption of area under various crops using, Nerlovian expectation model based on time-series data (Nerlove 1958; Abidoye and Mabaya 2014). Nerlovian expectation model has been applied to estimating the price expectation behaviour of farmers in relation to the previous year performance and analysing both the speed and level of adjustment of actual acreage towards a desired acreage (Nerlove 1958; Mythili 2012). However, price expectation theory is not appropriate when it comes to estimating the effect of household level characteristics at the farm level based on cross-sectional data. Many studies have tried to estimate the effect of household level characteristics on technology adoption and crop choice, notably using the choice theory or binary variable models such as logit, probit, and their updated versions like multinomial logit models (Chandio and Yuansheng 2018; Okuthe et al. 2000; Sheikh et al. 2003; Nagarajan et al. 2007; Idrisa et al. 2012; Udimal et al. 2017; Chianu et al. 2007; Issoufou et al. 2017; Uduji and Okolo-Obasi 2018; Ali 2021), but there are no studies available that focussed on the farm level characteristics affecting the area adoption of various crops in general and millets in particular in the Indian context. Therefore, this paper focus on filling this gap by analysing their relationship, which is crucial to policy formulation. This study is a modest attempt at drawing attention to the determinants of choice and area under millets in the Indian context.

Indian millets scenario

Millets are largely grown in Asia and Africa's semi-arid regions, with a total area of 39.21 M.ha (million hectares) and a production of 24.25 Mt (million tonnes) as of 2019-20 (FAO 2021) of which, India accounts for the largest area of 15.29 M.ha (26.6% of the world and 83% of Asia millets area) with a production of 10.24 M.t (36.08% of the world's production). Nevertheless, the area under millets shows a decline from 19 M.ha, on an average, in the 1960s to 9.71 Mha in 2020 (FAO 2021) - a decline of almost 49%. The major millets grown and consumed in India include jowar (sorghum), ragi (finger millet), bajra (pearl millet), kangni (foxtail millet), cheena (proso millet), kodo millet, barnyard millet, and small millets (NAAS 2013). Particularly, bajra, jowar, and ragi are the major millets produced and consumed in the country. Bajra is considered the fourth important crop grown predominantly in the states of Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat and Haryana. Bajra accounts for an area of 6.93 Mha with a mean production of 8.61 Mt and productivity of 1243 kg per ha in India for 2018-19. Ragi is produced at 1.17 M.t under 1.79 Mha and with 90% of it being produced in the states of Karnataka, Uttrakhand, Maharashtra, Tamil Nadu, Odisha and Andhra Pradesh. Bajra is cultivated under 4.9 Mha in India with a production of 4.8 Mt. According to Commission for Agricultural Costs and Prices (CACP) report (2020-21), jowar, bajra and ragi in India are produced at a cost of Rs.10829, Rs.10070.21 and Rs.16668.22 per acre, respectively as of 2017-18.

The changes in the existing production and consumption of millets are associated with the policies implemented in the country. Millet crops remain mostly

ignored in this regard, with policies favouring rice and wheat production since the era of Green Revolution. Recently, with a view to achieving nutritional security in the country, the government initiated some millet development schemes such as through Intensive Millets Production (INSIMP) under National Agriculture Development Programme (NADP), Rainfed Area Development Programme in 2011-12, Integrated Cereals Development Programmes in Coarse Cereals based Cropping Systems Areas (ICDP-CC) in 1994, National Agricultural Insurance Scheme-1999-2000, Weather Based Crop Insurance Scheme, Minimum Support Price, Pradhan Mantri Fasal Bima Yojana. All these are expected to favour an increased production of millets. Moreover, the National Food Security Act of 2013 included millets for the first time in the food security system as an important component, along with rice and wheat. Several states are also distributing millets such as bajra, jowar and ragi through the public distribution system along with rice and wheat. Efforts are also on to include minor millets in the mid-day meal scheme in government schools, especially in Karnataka and Telangana.

Data

The household level data on agricultural situation assessment collected by the National Statistical Office (NSO), Government of India through large scale National Sample Survey (NSS) has been used in this study to capture the spatial variations in the farm-household characteristics. This comprehensive national sample survey is conducted once in five years in all the states on a quinquennial basis. For our analysis purpose, we have used the latest survey data (77th round) pertaining to the year 2018-19 with the main aim of this survey being to collect information about cropping pattern and the production of various crops, input expenditure, output levels, sales, markets, value of output and demographic and farm level characteristics. The 77th round survey covered a sample size of over 58,040 households. The survey offers information on crop-wise cultivated area, expenses on farm inputs, value of commodities in Kharif season, and several farm household characteristics such as asset position, social and demographic details, and income sources. In addition, data on some institutional aspects related to agriculture such as credit, insurance, and extension contact, etc., have also been collected by the survey. As the cropping pattern in India remains more or less the same in recent times, 77th round survey data may resemble the current scenario with respect to the cropping pattern.

For analysis, we selected sample farms from the major millets growing states and ignored other states, where millets are not cultivated predominantly. Thus, the final sample size comprised 43,824 samples, of which only 40% of farmers have involved in millet production, and rest of the farmers did not cultivate any of millets.

Heckman sample selection model

A common problem we face in the observational farm household survey data on the cropping pattern and inputs usage relates to the possibility of a group of respondents reporting non-cultivation of millets and consequent output and resource use. In the case of such censored data, using ordinary least square (OLS) regression for estimating the influence of household characteristics on the area expansion under millets may produce biased, inconsistent, and inefficient coefficients. Also, the selection of sub-samples of millets growers and non-millets growers is subject to the problem of sample selection due to the absence of randomisation in the sub-samples selection from such a larger survey data. Using such sub-samples without controlling for the effect of non-randomisation on regression analysis may also result in a biased estimation. In this situation, Heckman developed a sample selection model to address this problem and the same we have employed to estimate the area adoption under millets using the notations of Yen and Rosinski (2008):

$$\log y = x'\beta + v \quad if \quad z'\alpha + u > 0 \,, \qquad (1)$$

$$y = 0 \qquad if \quad z'\alpha + u \le 0 \,,$$

where,

y is the dependent variable;

x and z are vectors of independent variables;

β and α stand for the conformable vectors of parameters; and

u and v are the error terms, which are distributed as bivariate normal with zero means and a finite covariance matrix:

$$\begin{bmatrix} u \\ v \end{bmatrix} \sim N\left\{\begin{matrix} 0 \\ 0 \end{matrix}\right\}, \begin{bmatrix} 1 & \sigma\rho \\ \sigma\rho & \sigma^2 \end{bmatrix} \qquad (2)$$

where,

σ represents standard deviation of v, and

ρ is the correlation between u and v.

Since the standard deviation of u is not known, it is considered as 1, and the binary selection outcomes take the value of 1 or 0.

The sample likelihood function is

$$L=\prod_{y=0}[1-\Phi(z'\alpha)]\prod_{y>0}\Phi\left[\frac{z'\alpha+\rho(\log y-x'\beta/\sigma}{(1-\rho^2)^{1/2}}\right]y^{-1}\frac{1}{\sigma}\phi\left(\frac{\log -x'\beta}{\sigma}\right) \quad (3)$$

where

y^{-1} is the Jacobian transformation from $\log y$ to y,

$\phi(.)$ is the standard normal probability density function (pdf), and

$\Phi(.)$ is the cumulative distribution function (cdf).

If the errors are independent ($\rho = 0$), equation 3 reduces to the same of a two-part model. The log likelihood function is separable into parameters α and [β, σ], and the assessment would be broken down to a probit model (to assess α) deploying the entire sample and a linear regression of $\log y$ on x (to assess β and σ) by only the non-limit sample.

We have estimated the marginal effects of the sample selection model by adopting the procedure of Yen and Rosinski (2008), where the conditional mean of the dependent variable y is

$$E(y|y>0)=\exp(x'\beta+\sigma^2/2)\,\Phi(z'\alpha+\sigma\rho)/\Phi(z'\alpha) \quad (4)$$

Since the marginal probability of a positive observation is

$$\Pr(y>0)=\Phi(z'\alpha) \quad (5)$$

the unconditional mean of y is

$$E(y)=\exp(x'\beta+\sigma^2/2)\,\Phi(z'\alpha+\sigma\rho) \quad (6)$$

Differentiating Equations (4), (5) and (6), we find the marginal effects on probability, conditional mean, and unconditional mean of a common element of x and z (say $x_j = Z_j$):

$$\partial\Pr(y>0)/\partial x_j=\phi(z'\alpha)\alpha_j \quad (7)$$

$$\partial E(y|y>0)/\partial x_j=[\Phi(z'\alpha)]^{-2}\exp(x'\beta+\sigma^2/2)\{[\Phi(z'\alpha)\phi(z'\alpha+\sigma\rho)-\phi(z'\alpha)\Phi(z'\alpha+\sigma\rho)]\alpha_j+\Phi(z'\alpha+\sigma\rho)\beta_j\} \quad (8)$$

$$\partial E(y)/\partial x_j=\exp(x'\beta+\sigma^2/2)[\phi(z'\alpha+\sigma\rho)\alpha_j+\Phi(z'\alpha+\sigma\rho)\beta_j \quad (9)$$

These marginal effects can be evaluated at the data points of interest, such as the sample means of the explanatory variables.

Selection of variables

The dependent variable in the Heckman sample selection (maximum likelihood) model is the area under millets in acre. The dependent variable in equation 1 is the natural logarithm of the total area on millets in a year. The following are the explanatory variables used in the model:

I. Household characteristics

1. Age of head of farm household (in years);
2. Educational level of head of farm household (dummy variables: 0 for illiterate; 1 for primary; 2 for high-school; 3 for higher secondary; 4 for diploma; 5 for collegiate level; and 6 for post graduate education)
3. Household size (in numbers);
4. Gender of household head (dummy variables: 0 for female-headed households and 1 for male-headed households);
5. Presence of regular salary earners (RSE) in household (dummy variables: 0 for absence of RSE; 1 for presence of RSE)
6. Non-farm income (dummy variables: 1 for having non-farm income generation activities and 0 for none).

II. Farm level characteristics

1. Farm size (in hectare);
2. Tenurial status (in acre);
3. Livestock activity (in numbers)
4. Irrigation sources (dummy variables: 0 for no irrigation; 1 for canal; 2 for surface; 3 for groundwater; 4 mixed; and 5 for others)

5. Family labour contribution (dummy variables: 0 for none; and 1 for contribution)
6. Choice of competitive crops (dummy variables: 0 for none; and 1 for respective crops).

III. Institutional characteristics

1. Training attended
2. Extension contact (in number)
3. Credit availed of agricultural purpose (dummy variables: 1 for credit availed, and 0 for credit not-availed);
4. Insurance policy available (dummy variables: 0 for none; and 1 for policy available;
5. Member in farmers organisation (dummy variables: 0 for no; and 1 for yes); and
6. Awareness regarding minimum support price (MSP) (dummy variables: 0 for no; and 1 for yes).

IV. Economic variables

1. Price of millets (in Rs. per kg);
2. Expenditure on fertilizers/acre (in Rs.);
3. Expenditure on labour/acre (in Rs.);
4. Expenditure on machine power/acre (in Rs.); and
5. Net farm income/acre (in Rs.).

While estimating the Heckman regression model, choosing independent variables is an issue and hence, we have used exclusion conditions for identifying the model parameters. Although there are no *a*-priori exclusion conditions for the current samples, we have used farm size in the area expansion equation, while three types of farm category (small, medium and large farmers) are included in the crop choice or selection equation. Also, the variables such as choice of other crops is included only in the choice equation, as it is expected to affect the millets choice more than area expansion. On the other hand, net farm income variable is included in the area expansion equation, as it is expected to affect the size of area than the choice of millets. Employing different set of variables in the two equations ensures that the model is identified. We have used *heckman* command in Stata (version 14.1) for estimating the log likelihood function of the Heckman sample selection model and its marginal effects at different levels.

Descriptive statistics

Cropping pattern

Examining the existing cropping pattern followed by the sample farmers helps understand the millet choice, area expansion, production and its determinants at the farm level. The cropping pattern followed by all the sample farmers as well as millet growing farmers is presented in Table 1 and 2. From Table 1, it is observed that, on an average, total cropped area accounts to 1.181 acre under unirrigated condition of which, millets occupy an average area of 0.28 acre. Also, it is noted that about 10% of the sample farmers are engaged in unirrigated-millets cultivation. Cereals, after millets, account for about 21% of the total cropped area grown by about 21% of the total farmers, followed by oilseeds, pulses and fibres. Under irrigated area, cereals grown constitute 48% of the total cropped area, followed by fodder crops, millets, oilseeds, sugar crops, pulses and vegetables (Table 1). We have tried to understand how diverse is the cropping pattern, when millets are considered as part of farm crops. It is interesting to note that bajra, grown solely accounts for about 39% of the total cropped area followed by jowar, pulses, fibres, fodder, oilseeds, ragi and maize. Paddy, maize and small-millet crops are grown on a small scale under unirrigated condition. Under irrigated condition, bajra grown accounts for more than 43% of the total cropped area, followed by paddy, jowar, oilseeds, fibre and fodder crops (Table 2). It is revealed that the cropping pattern varies across irrigated and millet growing areas with a higher proportion brought under bajra production under both irrigated and unirrigated conditions.

Farm household characteristics

Descriptive statistics related to farm household characteristics are presented in Table 3. About 40% of the sample farmers cultivate millets, including jowar, bajra, ragi, and other small-millets. Overall, agriculture and allied sectors is the primary source of income for 72% of the sample farmers, but only 54% for millet growing farmers rely the agricultural sector for their primary income, as compared to non-millet growing farmers (about 86%). Around 93% of the farmers are male, who live in households with more than five family members. Almost 90% of the farms are involved in their own faming activities. About 50% of the

Table 1 Cropping pattern followed by all sample farmers

Crops	Unirrigated condition						Irrigated condition					
	Area in acre	% to total cropped area	% of farmers	SD	Minimum	Maximum	Area in acre	% to total cropped area	% of farmers	SD	Minimum	Maximum
Cereals	0.254	21.49	21.25	0.804	0	20	0.675	48.03	46.75	1.793	0	68
Millets	0.280	23.69	10.43	1.213	0	28	0.145	10.32	8.49	0.653	0	29.5
Pulses	0.181	15.37	8.87	0.852	0	18.05	0.086	6.12	4.72	0.812	0	68
Sugar crops	0.001	0.07	0.69	0.048	0	5.75	0.075	5.34	5.22	0.538	0	17.41
Spices & Condiments	0.001	0.06	0.26	0.027	0	7	0.005	0.38	0.55	0.094	0	3.5
Fruits	0.006	0.47	0.69	0.144	0	14	0.008	0.54	0.67	0.224	0	18
Tubers	0.002	0.13	0.55	0.042	0	3.4	0.003	0.24	1.00	0.070	0	5.06
Vegetables	0.006	0.50	2.15	0.087	0	6	0.019	1.34	3.09	0.208	0	12
Oil seeds	0.231	19.58	7.22	1.255	0	66.62	0.185	13.20	6.68	1.385	0	61.8
Fibres	0.175	14.86	6.55	1.050	0	70	0.134	9.56	5.91	0.777	0	28.83
Dyes	0.000	0.00	0.00	0.000	0	0	0.000	0.00	0.01	0.004	0	3.13
Drugs	0.000	0.00	0.00	0.000	0	0	0.000	0.00	0.01	0.007	0	2.72
Fodder	0.044	3.71	2.09	0.451	0	17.06	0.060	4.29	8.56	0.476	0	20.03
Plantation	0.000	0.01	0.03	0.010	0	2	0.000	0.02	0.02	0.029	0	4
Flowers	0.000	0.00	0.01	0.001	0	0.52	0.001	0.06	0.13	0.027	0	3.5
Medicinal crops	0.000	0.00	0.01	0.002	0	0.4	0.001	0.07	0.03	0.070	0	8
Other food crops	0.001	0.06	0.32	0.036	0	9.05	0.000	0.01	0.38	0.015	0	2.72
Other non-food crops	0.000	0.01	0.01	0.009	0	0.92	0.007	0.48	0.01	0.175	0	16
Total cropped area	1.181						1.405					

Table 2 Cropping pattern followed by millet growing farmers

Crops	Unirrigated farmers						Irrigated farmers					
	Area in acre	% to total cropped area	% of farmers	SD	Minimum	Maximum	Area in acre	% to total cropped area	% of farmers	SD	Minimum	Maximum
Paddy	0.031	1.34	4.81	0.217	0	6.5	0.133	10.40	8.41	0.942	0	30
Maize	0.074	3.20	5.34	0.442	0	9	0.048	3.72	3.82	0.376	0	20
Wheat	0.000	0.02	0.12	0.028	0	2	0.001	0.10	0.16	0.058	0	3
Jowar	0.336	14.55	15.27	1.300	0	25	0.117	9.14	9.12	0.563	0	20
Bajra	0.900	38.98	37.65	1.963	0	28	0.555	43.32	34.08	1.140	0	20
Ragi	0.076	3.30	9.28	0.409	0	10	0.010	0.81	1.09	0.135	0	3
Small millets	0.009	0.38	1.92	0.123	0	4	0.002	0.18	0.22	0.084	0	7.42
Pulses	0.385	16.70	17.69	1.201	0	18.05	0.068	5.28	4.03	0.460	0	7
Sugar crops	0.000	0.01	0.03	0.010	0	0.5	0.029	2.25	1.27	0.467	0	16
Spices & Condiments	0.001	0.02	0.09	0.046	0	7	0.002	0.15	0.43	0.042	0	2
Fruits	0.006	0.26	0.34	0.243	0	14	0.006	0.43	0.56	0.111	0	3
Tubers	0.001	0.05	0.53	0.021	0	1	0.000	0.04	0.28	0.013	0	4
Vegetables	0.007	0.31	2.95	0.123	0	6	0.018	1.39	1.89	0.237	0	12
Oil seeds	0.082	3.55	5.46	0.578	0	25	0.091	7.13	5.00	0.569	0	13.2
Fibres	0.252	10.93	8.88	1.057	0	17.06	0.095	7.40	4.93	0.644	0	15
Dyes	0.000	0.00	0.00	0.000	0	0	0.000	0.00	0.03	0.008	0	3.13
Drugs	0.000	0.00	0.00	0.000	0	0	0.000	0.00	0.00	0.000	0	0
Fodder	0.136	5.88	5.40	0.784	0	17.06	0.092	7.15	7.23	0.788	0	20.03
Plantation	0.000	0.01	0.09	0.021	0	2	0.001	0.07	0.06	0.054	0	3.1
Flowers	0.000	0.00	0.00	0.000	0	0	0.000	0.01	0.09	0.008	0	1.5
Medicinal crops	0.000	0.00	0.00	0.000	0	0	0.000	0.02	0.06	0.020	0	1.99
Other food crops	0.001	0.02	0.09	0.062	0	9.05	0.000	0.00	0.40	0.000	0	0
Other non-food crops	0.000	0.00	0.00	0.000	0	0	0.012	0.90	0.00	0.279	0	10
Total cropped area	2.308						1.281					

Table 3 Descriptive statistics related to categorical variables

	Non-millets growing farmer (Number of farmers)	Millets growing farmer (Number of farmers)	All farmers (Number of farmers)
Household characters			
Primary source of income			
Agriculture			
Non-agriculture			
Household head age			
Youngster	14.03	22.84	17.59
Middle age	49.76	46.54	48.46
Elders	36.20	30.62	33.95
Household head Education			
Illiterate	35.31	41.91	37.97
Primary	37.84	36.87	37.45
High-school	12.74	10.44	11.82
Higher secondary	7.07	5.65	6.50
Diploma	0.98	0.87	0.94
Collegiate	4.83	3.14	4.15
Post-graduate	1.22	1.11	1.18
Gender			
Male	92.05	85.74	89.51
Female	7.95	14.26	10.49
Household size (average number)	4.96	4.69	4.87
Presence of regular salary earners			
No	99.90	99.62	99.79
Yes	0.10	0.38	0.21
Non-farm income generating activities			
No	92.62	96.56	94.21
Yes	7.38	3.44	5.79
Farm groups			
Small farmers	88.85	89.03	88.90
Medium farmers	8.77	8.20	8.61
Large farmers	2.38	2.77	2.49
Farm level characters			
Farm size (average acre)	2.213	1.863	2.092
Leased-in land (average acre)	0.321	0.180	0.273
Livestock (average numbers)	3.890	4.225	3.996
Irrigation sources			
No irrigation source	32.12	82.58	52.45
Canal	12.40	2.54	8.43
Surface	3.01	0.77	2.11
Groundwater	49.70	13.30	35.03
Mixed	0.99	0.21	0.67
Others	1.78	0.61	1.31

Contd...

	Non-millets growing farmer (Number of farmers)	Millets growing farmer (Number of farmers)	All farmers (Number of farmers)
Family labour contribution			
No	13.07	2.82	8.93
Yes	86.93	97.18	91.07
Institutional character			
Training attended			
No	98.34	99.15	98.66
Yes	1.66	0.85	1.34
Extension contact (average no. of media)	8.826	4.338	7.276
Credit availing for farming			
No	45.04	74.55	56.95
Yes	54.96	25.45	43.05
Credit outstanding (average Rs.)	78160.20	47728.94	76729.12
Insurance policy taken			
No	91.56	96.74	93.65
Yes	8.44	3.26	6.35
Member in farmer's organisation			
No	95.78	96.52	95.96
Yes	4.22	3.48	4.04
Awareness on minimum Support price			
No	76.04	97.04	84.52
Yes	23.96	2.96	15.48
Economic variables			
Price of millets (average Rs.)	17.71	18.17	17.87
Expenditure on fertilizers (average Rs.)	1870.17	831.03	1696.88
Expenditure on labour (average Rs.)	2158.29	928.39	1953.32
Expenditure on machine power (average Rs.)	1489.62	979.26	1404.51
Net farm income (average Rs.)	16497.65	5685.42	12761.18

farmers are of middle age group, followed by old age (34%) and youngsters (14%). About 38% of the farmers are illiterate, while 37% have only primary level of education. About 12 and 6.5% of the farmers have completed high- and higher-secondary schooling, respectively, while only 5% of the farmers have completed collegiate level education. A meagre 0.21 of the farmers are regular salary earners, while 6% are engaged in non-farming business activities such as wholesale and retail marketing, food and beverages production, construction, textiles, education, computer related works etc.

Among the sample farmers, almost 89% of the farmers are small farmers (<5 acres), 8.6% are medium farmers (5> & <10 acres) and only 2.5% are large farmers (>10 acres). On an average, farmers possess 2.09 acres of own land and 2.27 acres of operational holdings with 0.27 acres of leased-in land and 0.09 acres of leased out land. It is interesting to note that the total holding and operational size of land are 75% more in the case of millet growing farmers, as compared to other farmers. Also, about 50% of the total operational holdings is under irrigated condition. Farmers use different sources of irrigation for crop cultivation such as canal water, surface water, groundwater and other minor irrigation sources. Among the sample farmers, more than 35% of the farmers rely on groundwater sources, 8% on canal water and 2% on surface water. In particular, more than 80% of the millet growing farmers operate under unirrigated condition, while only

32% of the non-millet growing farmers operate under unirrigated condition.

With respect to institutional characteristics, only 4% of the farmers have membership with farmers' organisation and 1.34% have attended government training programmes. Also, more than 80% of the farmers are not aware of the minimum support price (MSP) policy. It is observed that sample farmers get farm-related technical advice from different sources, including mass media, social media, extension officers, scientist, agro-clinic, call-centres, NGOs etc. Overall, on an average, farmers obtain farm-related information from nine different sources. In the case of financial services, about 43% of the farmers have obtained loans-from both institutional and non-institutional agencies for the purpose of agricultural operations and household management with an outstanding amount of over one lakh rupees. In particular, 25% of the total millet-growing farmers have availed of loans with the outstanding amount of Rs.47729, while more than 54% of the non-millet growing farmers have availed of loans with the outstanding amount of Rs.78160. It is also noted that only 6% of the farmers have an insurance policy.

Eventually, economic and technical parameters can determine significantly area adoption and the size of area under any crop. The average price of millets is observed at Rs.18 per kg. Overall, farmers have spent Rs.1,697 on fertilizers, Rs.1,953 on labour and Rs.1,404 on machine power per acre. It is also noted that per acre cost of these inputs incurred by non-millet growing farms amounts to 44, 43 and 62%, respectively, higher than millets growing farms, indicating that farms with millet crops are less input intensive. Moreover, economic viability of a farm in terms of generating income from various crops and livestock activities is expected to affect the amount of millets production. It is observed that the net farm income amounts to Rs.5,685 in millet growing farms, while it is three times higher for non-millet growing farms at Rs.16,497 per farm.

Millet choice and area expansion across major household characteristics

Area adoption under millet crops across major household characteristics is presented in Table 4. Larger farmers, as expected, have adopted more area under millets than medium and small farmers. On an average, large famers cultivated crops over 6.43 acre followed by medium farmers (3.38 acre) and small farmers (1.32 acre). It is also noted that small farmers cultivate millets over 65% of their total cropped area. It is more than the medium (53%) and large farmers (46%). Elder farmers grow millets over an average of 2.05 acre followed by middle age and young farmers – but youngster are observed to have prioritised millets over other crops as 65% of their total cropped area is under millet crops as compared to middle age (59%) and elders (54%). It is interesting to note that graduate farmers favour millets production over other crops. For instance, graduate and postgraduate farmers have not only adopted more area under millets, but also they have allocated 65% of their total cropped area to millets. Across gender, female farmers preference for millet crops is more than male farmers. Farmers with no irrigation facilities have allocated more area (2.05 acre) to millets. Moreover, more than 50% of the total cropped area is allocated to the millet crops by farmers, using all the available irrigation sources, excepting canal irrigation. Farmers using canal irrigation have allocated only 39 per cent of the total cropped area to millets, indicating that the possibility of millets production under canal irrigation system is less. Farmers with access to credit facility adopting millet crops accounts to 26% lesser than their counterparts, but they have allocated a higher proportion of the cropped area to millets, as compared to non-credit holders, indicating that credit facility helps more area allocation to millets.

Results and discussion

Determinants of area adoption under millets

We estimated the functional relationship between the area expansion under millets by farm households and its key determinants-farm household level characteristics (Table 5). As the present data obtained from the household survey is subject to the problem of sample selection for choosing sub-samples of millet farmers and non-millet famers without any randomisation procedure followed, the estimate of parameters using OLS regression is expected to be biased. To avoid such biased results due to sample selection problems, Heckman sample selection model has been used for estimating the parameters of

Table 4 Acreage under millet crops by household characters

Variables	Irrigated Jowar	Unirrigated Jowar	Irrigated Bajra	Unirrigated Bajra	Irrigated Ragi	Unirrigated Ragi	Irrigated Small millets	Unirrigated Small millets	Total area under millets	% share to total cropped area
Age: Youngster	0.109	0.349	0.459	0.683	0.009	0.079	0.001	0.002	1.692	64.94
Middle age	0.107	0.328	0.462	0.704	0.007	0.101	0.000	0.014	1.724	59.08
Old age	0.133	0.4	0.492	0.88	0.026	0.111	0.004	0.007	2.053	54.18
Education: Illiterate	0.107	0.343	0.403	0.964	0.014	0.135	0.000	0.009	1.976	56.19
Primary	0.113	0.312	0.457	0.709	0.013	0.087	0.004	0.013	1.708	58.92
High-school	0.158	0.258	0.566	0.345	0.026	0.111	0.000	0.006	1.47	54.09
Higher secondary	0.075	0.634	0.545	0.521	0.002	0.052	0.000	0.004	1.834	58.88
Diploma	0.293	0.67	0.452	0.387	0.000	0.087	0.000	0.002	1.893	54.48
Collegiate	0.131	0.729	0.806	0.676	0.018	0.013	0.000	0.003	2.377	65.94
Post-graduate	0.177	0.22	0.735	1.914	0.000	0.001	0.000	0.001	3.048	69.85
Sex: male	0.115	0.365	0.472	0.787	0.013	0.097	0.002	0.01	1.861	57.00
Female	0.134	0.257	0.472	0.501	0.031	0.144	0.001	0.004	1.544	69.99
Farm category: small farmers	0.096	0.234	0.42	0.433	0.016	0.11	0.002	0.01	1.32	65.18
Medium farmers	0.245	0.77	0.792	1.472	0.007	0.084	0.002	0.01	3.381	52.75
Large farmers	0.169	1.361	0.622	4.267	0.002	0.01	0.000	0.006	6.437	46.26
Irrigation sources: No irrigation source	0.011	0.579	0.013	1.265	0.004	0.175	0.000	0.016	2.064	59.46
Canal	0.299	0.141	0.51	0.356	0.041	0.057	0.000	0.007	1.411	39.32
Surface	1.048	0.469	0.139	0.132	0	0.024	0.000	0.004	1.816	53.22
Groundwater	0.208	0.089	1.022	0.195	0.021	0.013	0.003	0.002	1.554	55.86
Mixed	0.122	0.018	1.297	0.017	0.119	0.231	0.000	0.000	1.804	58.18
Others	0.046	0.072	1.782	0.001	0.099	0.022	0.000	0.000	2.022	82.62
Non-farming income	0.042	0.725	0.383	0.611	0.01	0.053	0.000	0.003	1.827	58.00
No non-farming	0.121	0.331	0.478	0.773	0.014	0.105	0.002	0.01	1.834	57.75
No credit availed	0.143	0.437	0.480	0.898	0.012	0.094	0.002	0.007	2.074	55.57
Credit availed	0.084	0.258	0.462	0.597	0.016	0.110	0.001	0.012	1.542	61.75
No MFO	0.242	0.462	0.423	0.731	0.02	0.047	0.002	0.003	1.93	55.89
MFO	0.112	0.352	0.474	0.764	0.014	0.103	0.001	0.01	1.83	57.84

Table 5 Sample selection model for millets area adoption (Maximum likelihood function)

Variables	Crop selection equation		Area expansion equation	
	Coefficients	Standard errors	Coefficients	Standard errors
Household head age				
(Reference : Youngster)				
Middle age	-0.006	0.075	0.028	0.066
Elders	0.121	0.080	-0.009	0.071
Household head Education				
(Reference : Illiterate)				
Primary	0.061	0.060	-0.102**	0.049
High-school	0.316***	0.089	-0.121	0.078
Higher secondary	0.312***	0.100	-0.214**	0.090
Diploma	0.587	0.362	-0.123	0.482
Collegiate	0.255*	0.147	-0.173	0.153
Post-graduate	0.333*	0.185	-0.146	0.124
Gender	-0.055	0.090	-0.192**	0.081
Household size (average number)	0.017*	0.010	0.022***	0.008
Presence of regular salary earners	-0.097	0.365	0.269*	0.146
Non-farm income generating activities	0.112	0.100	-0.253**	0.099
Farm level characteristics				
Farm size (average acre)	-	-	0.117***	0.008
Farm category (reference: small farmers)				
Medium farmers	0.612***	0.078	-	-
Large farmers	0.546***	0.152	-	-
Leased-in land (average acre)	0.089***	0.021	0.083	0.022
Livestock (average numbers)	0.021**	0.009	-0.007**	0.003
Irrigation sources				
(Reference : no irrigation source)				
Canal	-0.940***	0.126	-0.059	0.175
Surface	-0.349**	0.173	0.163	0.122
Groundwater	-0.304***	0.058	0.060	0.052
Mixed	-1.138***	0.322	0.147	0.266
Others	-0.373**	0.163	0.372**	0.189
Family labour contribution	0.195**	0.082	-0.068	0.082
Choice of cereals	-1.710***	0.063	-	-
Choice of vegetables	-0.257**	0.125	-	-
Choice of pulses	-0.428***	0.064	-	-
Choice of oilseeds	-1.415***	0.093	-	-
Choice of fodder	-0.178**	0.075	-	-
Institutional characteristics				
Extension contact (average no. of media)	-0.128	0.083	0.059	0.067
Credit availing for farming	0.054	0.053	0.152***	0.047
Insurance policy taken	0.198**	0.091	-0.025	0.061
Member in farmers' organisation	0.076	0.146	-0.040	0.165
Awareness regarding Minimum Support Price	-0.476***	0.065	0.125	0.067

Contd...

Variables	Crop selection equation		Area expansion equation	
	Coefficients	Standard errors	Coefficients	Standard errors
Economic variables				
Price of millets (average Rs.)	0.081***	0.013	0.000	0.008
Net farm income (average Rs.)	-	-	-0.001	0.001
Expenditure on fertilizers (average Rs.)	-0.054*	0.030	-0.046**	0.019
Expenditure on labour (average Rs.)	-0.029**	0.013	-0.028	0.020
Expenditure on machine power (average Rs.)	-0.023	0.020	-0.018	0.019
Constant	0.281	0.801	-0.314*	0.638
Rho	-0.679***	0.043		
Sigma	0.823***	0.024		
Lambda	-0.559***	0.047		
Likelihood ratio chi2(1) = 108.74***				

Notes *** - significance at 1% level; ** - significance at 5%; * - significance at 10%

determinants of area under adoption under millets (Yen and Rosinski (2008). The results of the estimated equations of millets adoption and its area expansion are presented in Table 5. From the table, it is found that the estimated error correlation coefficient (-0.56) between the equations of millets adoption decision and area expansion, and its corresponding covariance term (0.82), is significant (P<0.01); and the independence of the error terms of the adoption and area expansion equations is rejected. This emphasizes the importance of selectivity correction in this analysis. Moreover, most of the estimated coefficients in both the equations are found to be statistically significant.

With a separate equation to accommodate the sample selection and level, and with logarithmic transformation in the dependent variables, the effects of explanatory variables on the probability of crop choice and area expansion are non-trivial. In order to explore the impact of farm household characteristics on the choice of millets, and on the extent of area under millet crops, we worked out the marginal effects on probability, conditional level (current farmers), and unconditional level (average farmers) (Equations 7–9). The effects on conditional level or conditional marginal effects, measure how a specific independent variable changes the extent of area cultivated under millets across existing millets growing farms. The effects on probability or the marginal effects of probability, explain the binary decision of adopting millets or not i.e., these explain how independent variables influence farmers, who have not adopted millets, into adopting. The effects on the unconditional level assess, overall, what contributes to area expansion by increasing (or decreasing) the probability or conditional level.

Impact of changes in economic factors

Table 6 shows the marginal effects of independent variables on millets choice and level of area expansion. As expected, the market price of millets has a positive and significant effect on the choice of millets production i.e., farmers would be 1.73% more likely to choose millets production, if the price of millets increased by Rs.10/- per kg. Also, the effect of millet price on extent the level of area expansion under millets shows a positive and significant relationship both at the conditional and unconditional levels. If the price of millets increased by Rs.10/- per kg, millet acreage would be increased by 0.03 acre at the conditional level and 0.005 acre at the unconditional level. These results indicate that increased price of millets encourages farmers to adopt more area under millets, as a higher price provides more remuneration to the farmers.

Farm expenditure on fertilizer and labour shows a negative and significant effect on millet adoption and its area expansion. For instance, a Rs.1000 increase in the farm expenditure on fertilizer and labour would cause a decline in the probability of millets adoption by famers by 1.15% and 0.62%, respectively. In addition, a Rs.1000 increase in the farm expenditure

Table 6 Estimated marginal effect of independent variables

Variables	Marginal effects probability (%)		Marginal effect at the conditional level		Marginal effect at the unconditional level	
	Coefficients	Standard errors	Coefficients	Standard errors	Coefficients	Standard errors
Middle age groups	-0.12	0.016	0.025	0.059	0.007	0.016
Old age groups	2.60	0.017	0.040	0.063	0.005	0.018
Primary	1.27	0.012	-0.076	0.046	-0.023*	0.012
High-school	6.92***	0.020	0.007	0.075	-0.014	0.024
Higher secondary	6.82***	0.023	-0.088	0.082	-0.045	0.027
Diploma	13.48	0.091	0.107	0.455	0.003	0.183
Collegiate	5.50*	0.033	-0.069	0.125	-0.034	0.044
Post-graduate	7.31*	0.043	-0.011	0.119	-0.021	0.038
Gender of farmers	-1.16	0.019	-0.215***	0.078	-0.055***	0.021
Household size	0.36*	0.002	0.029***	0.008	0.007***	0.002
RSE	-2.02	0.074	0.229	0.148	0.064	0.040
Non-farm income	2.43	0.022	-0.208**	0.094	-0.069**	0.029
Farm size	-	-	0.117***	0.008	0.033***	0.002
Tenure	1.90***	0.005	0.120***	0.021	0.029***	0.006
Livestock rearing	0.44**	0.002	0.001	0.004	-0.001	0.001
Canal	-18.60***	0.021	-0.461***	0.149	-0.053**	0.026
Surface	-7.90**	0.037	0.022	0.125	0.022	0.032
Groundwater	-6.96***	0.014	-0.062	0.046	-0.002	0.014
Mixed	-21.40***	0.044	-0.346*	0.192	-0.031	0.027
Others	-8.42**	0.034	0.220	0.159	0.072*	0.039
Family labour contribution	4.00**	0.016	0.013	0.073	-0.005	0.018
Extension contacts	-2.72	0.018	0.007	0.060	0.008	0.017
Credit availing	1.16	0.011	0.174***	0.042	0.046***	0.012
Insurance	4.36**	0.021	0.055	0.059	0.005	0.018
Member in FO	1.64	0.032	-0.010	0.146	-0.007	0.045
MSP awareness	-9.54***	0.012	-0.075	0.062	-0.001	0.014
Price of millets	1.73***	0.003	0.033***	0.006	0.005***	0.002
Net farm income	-	-	-0.001	0.001	0.000	0.000
Expenditure on fertilizers	-1.15*	0.006	-0.068***	0.020	-0.016***	0.005
Expenditure on labour	-0.62**	0.003	-0.040**	0.019	-0.010*	0.005
Expenditure on machine power	-0.49	0.004	-0.027	0.019	-0.006	0.005
Medium farmers	14.52***	0.021	0.238***	0.034	0.045***	0.009
Large farmers	12.84***	0.039	0.215***	0.055	0.039***	0.013
Choice of other cereals	-46.75***	0.016	-0.694***	0.050	-0.120***	0.015
Choice of vegetables	-5.18**	0.024	-0.107**	0.055	-0.015**	0.007
Choice of pulses	-8.33***	0.011	-0.179***	0.029	-0.026***	0.004
Choice of oilseeds	-24.38***	0.011	-0.623***	0.052	-0.084***	0.006
Choice of fodder	-3.65**	0.015	-0.074**	0.031	-0.011**	0.004

Notes *** - significance at 1% level; ** - significance at 5%; * - significance at 10%

on these inputs would reduce the size of area under millets by 0.068 and 0.04 acre, respectively, at the conditional level and 0.016 and 0.01 acre, respectively, at unconditional level. It is understood that farm input intensification leads to a reduction in the area under millets. Conversely, a study points out that the absence of input intensification in millet farming can limit crop production (Muthamilarasan and Prasad 2021).

Impact of changes in the demographic variables

Gender of farmers has no significant role in the choice of millets, but has a negative effect on area increase under millets. If a farmer is female, the size of area under millets decreases by 0.215 acre at the conditional level and 0.055 acre at the unconditional level. Similarly, age level has no significant effect on the choice of millets and area expansion. However, it is observed that education has a significant positive relationship with the choice of millets, i.e., farmers with high school, higher secondary and collegiate level education prefer to grow millets. Surprisingly, education does not have a significant effect on level of area adoption under millets.

Household size has a positive and significant effect on the choice of millets and its area expansion. For instance, an increase in the household size by one member increases the probability of millet adoption by 0.36%, while the size of area under millets increases by 0.029 acre at conditional level and 0.007 acre at the unconditional level. In line with this finding, family labour contribution to the farm also has a positive relationship with millets cultivation i.e., those farms contributing family labour are 4% more likely to adopt millets cultivation on the farm. Thus, it is revealed that a larger family size facilitates more area adoption under millets. Porgo et al., (2018) found family labour as a significant determinant of area under millets. It might be noted that significant farming activities like sowing, weeding and harvesting are carried out by family members only, specifically in the case of small farmers (Rouamba et al. 2021). Sdrali (2006) noted that households with a large family size were engaged more in pearl millet production than households with a small family size. Non-farm income generating activities affect negatively the area expansion under millets i.e., if there is any non-farm income generating activity in the farm households, there would be a decline by 0.208 acre at the conditional level and 0.069 acre at the unconditional level. In general, the effect of non-farming activities on agricultural production is ambiguous. On the one hand, it is assumed that non-farm activities act as alternative sources of income and employment for farmers and help buy more of inputs used in crop production. Also, non-farm activities mainly help commercial farming (Braun et al. 1991). On the other hand, non-farming activities have a negative effect on subsistence farming by withdrawing a portion of family labour force from farming and subsequently decrease production (Wang et al. 2011). Our study results also conform to the latter that non-farming activities are not favourable to the cultivation of millets. This could be due to the less remunerative nature and lack of commercialisation of millets production in rural areas.

Impact of changes in the farm level characteristics

Regarding farm characteristics, farm size, other crop competitiveness, livestock rearing, irrigation sources and family labour contribution are found to have a significant impact on adoption of millets production. When compared to small farmers, medium and large farmers are 14.52% and 13%, respectively, more likely to adopt millets production on the farm. At the conditional level, medium and large farmers are expected to grow millets over 0.238 acre and 0.215 acre more, respectively, vis-a-vis small farmers. Similarly, it is 0.045 acre and 0.039 acre, respectively, at the unconditional level. It is also noted that 1 acre increase in the size of farm land leads to an increase in the area under millets by 0.117 acre at the conditional level and 0.033 acre at the unconditional level. All these imply that farmers with a relatively larger size of land may have more cultivatable space to experiment with a variety of crops, including millets. Rearing of livestock has a positive effect on millets cultivation i.e., if a farmer rears livestock in the farm household, millets have a 0.44% chance of being adopted. It is attributed that leaves and straws of millets can be used as important feed materials in the crop–livestock systems. In the developing countries, most of the millet crops are used for dual purposes - grain provides food for humans and by-products are used as feed for livestock (Herrero et al. 2010). Harinarayana et al., (2005) observe that jowar is a gifted millet, as it provides food, feed, stover to millions of poor farm families and their livestock. Unexpectedly, tenurial

status of a farm increase the probability of increased adoption of millets i.e., 1 acre increase in the leased-in land increases the probability of millets production by 1.9%. Also, increased area of leased-in land by one acre increases the area under millets by 0.12 acre at the conditional level and 0.029 acre at the unconditional level. The positive effect on millets area expansion may be attributed to cheap availability of cultivable land in rain-fed regions.

Farmers reliant on irrigation sources for crop production are found less likely to adopt millets cultivation. For instance, a farm dependent on canal water for irrigation is 18.6% less likely to cultivate millet crops. Similarly, farmers with surface and groundwater irrigation are 7.9% and 7%, respectively, less likely to adopt millets production. It is noted that a farm accessing water from various sources is 21.4% less likely to adopt millets production. When compared to rain-fed farms, farms having canal irrigation facility are expected to reduce area expansion under millets by 0.461 acre at the conditional level and 0.053 acre at the unconditional level. All of these findings suggest that millets production is predominantly rainfed. It is also found that production of other crops such as cereals, vegetables, pulses, oilseeds and fodder crops restrict the production of millets. For instances, the probability of millets production is 47% less, in the case of a farm cultivating cereals. Similarly, millets are 24.38, 8.33, 5.18 and 3.65% less likely to adopt in the case of a farm cultivating oilseeds, pulses, vegetables, and fodder crops, respectively. Also, cultivation of cereal and oilseed crops leads to more than half of millets area at the conditional level.

It's also worth noting that non-farm income generating activities are inversely related to the area expansion under millets. In the case of a farmer generating income from non-farm activities, there is a possibility of area under millets being reduced by 0.208 acre at the conditional level and 0.069 acre at the unconditional level. This shows that the scope for area adoption under millets is less, if farmers are engaged in income generating business activities outside of the farm.

Impact of changes in the institutional factors

We were also interested in finding the effect of institutional characteristics like extension contact, training attended, membership with famers' organisation, minimum support price, credit availing and insurance on the choice of millets and area expansion. The results show that only awareness regarding MSP and insurance has a significant effect on the choice of millets. Farmers being aware of MSP are 9.54% less likely to choose millets production, while farmers being aware of crop insurance schemes are 4.36% more likely to choose millets. It is observed that both credit and insurance positively and significantly affect the area expansion under millet crops. For instances, the area under millets shows an increase by 0.174 acre at the conditional level and 0.046 acre at the unconditional level in the case of farmers availing of credit facilities. Surprisingly, a positive effect of credit on millets production is noteworthy. Jerop et al., (2020) found that finger millet growing households' credit availing strongly correlated with its adoption decision, while credit availability supported the production of cash/commercial crops (Kokoye 2013; Porgo et al. 2018; Rashid 2002).

Conclusion

In the recent years, more attention has been placed on millets production and consumption for a variety of reasons. Millets can be used as an instrument for addressing various problems such as global malnutrition, poor diet, poverty, climate change, nutritional security, environmental problems associated with agriculture. Further, millets require low amounts of input, short-term period and are drought resistant. Whenever there is a failure of rains, farmers tend to use growing-millet crops as animal fodder. Further, millets are climate-resilient, compared to other crops like paddy and wheat. However, the choice of millets cultivation is subject to farm household, economic, demographic and institutional characteristics. In this study, we have made an attempt to contextualize the millets production in India by estimating the major determinants of millets cultivation at the farm level.

Although the increased price of millets has contributed for higher probability of millets adoption, the magnitude of area expansion under millets is found very less. In line with this, awareness about MSP for millets is negatively associated with the choice of millets though the MSP is 1.5 times more than the cost of cultivation. Moreover, the findings also reveal that though higher educational levels of farmers have had a significant effect on millets choice, there is no

significant effect on the area expansion under millets. This highlights that millets are still seen as inferior crops, even by farmers who already grow them. On the other hand, extension activities are found to have no significant role in the decision making behaviour towards millets production. It is recommended to encourage agricultural extension workers, scientists, and other agricultural stakeholders towards organizing campaigns, training programs, and frequent contacts with farmers in order to raise awareness regarding the benefits of millets in terms of nutrient richness, production efficiency and environmental benefits in comparison to the production of other cereal grains. Moreover, skill development programmes in the areas of production, processing and value addition of millet products need to be organised for all the millet growing farmers, specifically female farmers.

The study revealed that leased-in practice encourages more area coverage under millets, indicating that cultivable land, in particular rain-fed area suitable for millets, may be made available at a cheaper rate to increase the area. It is also observed from the estimated results that farmers depending on irrigation sources of any kind for crop production are negatively interested in millets production, as compared to rain-fed farmers. All these indicate that a wide, holistic and inclusive policy needs to be developed to integrate and encourage rain-fed and rental farming with promising new technologies in millets production, processing and marketing. Cultivation of other crops such as cereals, pulses, oilseeds, vegetables and fodder has affected tremendously the choice and area extent under millets. The main reasons behind the shift from millets production to other crops might be low productivity and remuneration, inadequate input subsidies and credit, price incentives and changes in taste and preferences of consumers. Specifically, subsidised supply through the public distribution system (PDS) is one of the major reasons for increased area adoption under cereals, but millets are underutilized in the PDS system. Hence it is important to create a generalised demand for millets-based products, along with productivity enhancement to help millets growing farmers in realising better prices for their products in the market. Moreover, value addition and modernization of the processing sector of millets may be created in the major millets growing regions. This could help boost the demand for millets and millets-based food products. Improvement and dissemination of post-harvest processing technologies for millets in rural areas could create employment and agribusiness opportunities and subsequently increase the use of millets based food items.

The study findings demonstrate that credit for agricultural purposes and insurance policies have encouraged millets production. This positive effect should be noted, as it is well-known that credit encourages only commercial crops or commercial farming. Hence, it is recommended that eliminating constraints in accessing formal agricultural credit from the nationalised and cooperative banks may help increase the area under millets. Also, governments, combined with bank officials, should organise special loan-melas for the stakeholders involved in the millets production and processing, so that millet growing farmers and processors are able to avail of credit facilities easily and increase the millets based food production.

As millets are the major source of many nutrients, removing barriers to their production, distribution and consumption can help reduce the problem of nutrition-related insecurity and malnutrition cases in the country. The study results are intended to benefit agricultural policy makers, extension services, government and private agencies towards undertaking appropriate measures related to the production and use of millets in India.

References

Abidoye, B O, and E Mabaya. 2014. Adoption of genetically modified crops in South Africa: Effects on wholesale maize prices. *Agrekon 53*(1): 104-123.

Ali, E. 2021. Farm households' adoption of climate-smart practices in subsistence agriculture: Evidence from Northern Togo. *Environmental Management 67*(5): 949-962.

Anbukkani, P, S J Balaji, and M L Nithyashree. 2017. Production and consumption of minor millets in India-A structural break analysis. *Annals of Agricultural Research 38*: 1-8.

Bansil, P S. 1999. *Demand for Food Grains by 2020 AD*. Observer Research Foundation, New Delhi.

Bergamini, N, S Padulosi, S B Ravi, and N Yenagi. 2013. *Minor millets in India: a neglected crop goes mainstream,* 313-325. Routledge: London, UK.

Chand, R. 2007. Demand for Food grains. *Economic & Political Weekly* 42(52): 10-13.

Chandio, A A, and J I A N G Yuansheng. 2018. Determinants of adoption of improved rice varieties in northern Sindh, Pakistan. *Rice Science 25*(2):103-110.

Chandrakanth, M G, and B M Akarsha. 2011. Green development for sustainable agriculture. *FKCCI Journal* 32 (5): 11-14.

Chatterjee, S, A Rae, R Ray, and M Universuty. 2006. Food consumption, trade reforms and trade patterns in contemporary India: How do Australia and NZ fit in. In *Conference Paper, Massy University, New Zealand: Department of Applied and International Economics*.

Chengappa, P G, L Achoth, A Mukherjee, B R Reddy, P C Ravi, and V Dega. 2007. Evolution of food retail chains in India. *Agricultural Diversification and Smallholders in South Asia. New Delhi: Academic Foundation*.

Chianu, J N, H Tsujii, and J Mbanasor. 2007. Determinants of the decision to adopt improved maize variety by smallholder farmers in the savannas of northern Nigeria. *Journal of Food Agriculture and Environment 5*(2): 318.

Food and Agriculture Organization (FAO), 2021. FAOSTAT Database. (http://www.fao.org/faostat/)

Frison, E A, I F Smith, T Johns, J Cherfas, and P B Eyzaguirre. 2006. Agricultural biodiversity, nutrition, and health: making a difference to hunger and nutrition in the developing world. *Food and nutrition bulletin* 27(2): 167-179.

Harinarayana, G, N P Melkania, B V Reddy, S K Gupta, K N Rai, and P S Kumar. 2005. Forage potential of sorghum and pearl millet. In *Forage potential 343 of sorghum and pearl millet,* 292-321. ICRISAT, Patancheru. URI: http://oar.icrisat.org/id/eprint/4394

Hawtin, G. 2007. Underutilized plant species research and development activities—review of issues and options. GFU/ICUC. International Plant Genetic Resources Institute, Rome, Italy.

Herrero, M, P K Thornton, A M Notenbaert, S Wood, S Msangi, H A Freeman, D Bossio, J Dixon, M Peters, J van de Steeg, and J Lynam. 2010. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. *Science*, *327*(5967): 822-825.

Idrisa, Y L, B O Ogunbameru, and M C Madukwe. 2012. Logit and Tobit analyses of the determinants of likelihood of adoption and extent of adoption of improved soybean seed in Borno State, Nigeria. *Greener Journal of Agricultural Sciences 2*(2): 37-45.

Issoufou, O H, S Boubacar, T Adam, and B Yamba. 2017. Determinants of adoption and impact of improved varieties on pearl millet productivity in Niger. *African Crop Science Journal 25*(2): 207-220.

Jerop, R, G Owuor, P Mshenga, and P Kimurto. 2020. Effects of finger millet innovations on productivity in Kenya. *Cogent Food & Agriculture 6*(1): 1830476.

Kokoye, S E H, S D Tovignan, J A Yabi, and R N Yegbemey. 2013. Econometric modeling of farm household land allocation in the municipality of Banikoara in Northern Benin. *Land use policy 34*:72-79.

Kumar, P, A Kumar, S Parappurathu, and S S Raju. 2011. Estimation of demand elasticity for food commodities in India. *Agricultural Economics Research Review* 24(1): 1-14.

Lapar, M L A, M Choubey, P Patwari, A Kumar, I Baltenweck, M A Jabbar, and S Staal. 2010. *Consumer preferences for attributes of raw and powdered milk in Assam, Northeast India*. ILRI, 103.

Lata, C, S Gupta, and M Prasad. 2013. Foxtail millet: a model crop for genetic and genomic studies in bioenergy grasses. *Critical Review in Biotechnology* 33: 328–343.

Muthamilarasan, M, and M Prasad. 2021. Small millets for enduring food security amidst pandemics. *Trends in Plant Science 26*(1): 33-40.

Muthamilarasan, M, A Dhaka, R Yadav, and M Prasad. 2016. Exploration of millet models for developing nutrient rich graminaceous crops. *Plant Science 242*: 89-97.

Mythili, G. 2012. Supply response of Indian farmers: Pre and post reforms, Working Paper series – 2006-009, Indira Gandhi Institute of Development Research, Mumbai.

NAAS. 2013. Role of Millets in Nutritional Security of India. Policy Paper No. 66, National Academy of Agricultural Sciences, New Delhi, 16.

Nagarajan, L, M Smale, and P Glewwe. 2007. Determinants of millet diversity at the household farm and village community levels in the drylands of India: the role of local seed systems. *Agricultural Economics 36*(2):157-167.

Nagarajan, L, M Smale, and P Glewwe. 2005. Comparing farm and village-level determinants of millet diversity in marginal environments of India: the context of seed systems. *International Food Policy Research Institute*, Discussion paper 139.

Nerlove, M. 1958. *The Dynamics of Supply: Estimation of Farmers' Response to Price,* John Hopkins Press.

Okuthe, I K, F U Ngesa, and W W Ochola. 2000. Socio-economic determinants of adoption of improved sorghum varieties and technologies among smallholder farmers in Western Kenya. *Ministry of Agriculture and Egerton University, Kenya*.

Padulosi, S, and I Hoeschle-Zeledon. 2004. Underutilized plant species: what are they?, *LEISA* 20(1): 56.

Porgo, M, J K Kuwornu, P Zahonogo, J B D Jatoe, and I S Egyir. 2018. Credit constraints and cropland allocation decisions in rural Burkina Faso. *Land Use Policy 70:* 666-674.

Radhakrishna, R. 2005. Food and nutrition security of the poor: emerging perspectives and policy issues. *Economic and Political weekly* 40(18): 1817-21.

Rashid, S, M Sharma, and M Zeller. 2002. Micro-lending for small farmers in Bangladesh: does it affect farm households' land allocation decision? Markets and structural studies division. International Food Policy Research Institute, MSSD discussion paper No. 45.

Rouamba, A, H Shimelis, I Drabo, M Laing, P Gangashetty, I Mathew, E Mrema, and A I T Shayanowako. 2021. Constraints to pearl millet (Pennisetum glaucum) production and farmers' approaches to Striga hermonthica management in Burkina Faso. *Sustainability 13*(15): 8460.

Sakamoto, S. 1982. Waxy endosperm and perisperm of cereals and grain Amaranth and their geographical distribution. *Journal of the Japanese Society of Starch Science* 29: 41–59.

Sdrali, D. 2006. Effects of socio-demographic and economic factors on food expenditure in a prefecture of Greece. Dissertation for the Award of PhD at Harokopio University of Athens, Greece. 187.

Sheikh, A D, T Rehman, and C M Yates. 2003. Logit models for identifying the factors that influence the uptake of new 'no-tillage'technologies by farmers in the rice–wheat and the cotton–wheat farming systems of Pakistan's Punjab. *Agricultural systems 75*(1): 79-95.

Smith, I F, and T Longvah. 2009. Mainstreaming the use of nutrient-rich underutilized plant food resources in diets can positively impact on family food and nutrition security – data from Northeast India and West Africa. *Acta Horticulturae*, 806: 375–384.

Food and Agriculture Organization (FAO). 2021. FAOSTAT Database.

Udimal, T B, Z Jincai, O S Mensah, and A E Caesar. 2017. Factors influencing the agricultural technology adoption: The case of improved rice varieties (Nerica) in the Northern Region, Ghana. *Journal of Economics and Sustainable Development 8*(8): 137-148.

Uduji, J I, and E N Okolo-Obasi. 2018. Adoption of improved crop varieties by involving farmers in the e-wallet program in Nigeria. *Journal of Crop Improvement 32*(5): 717-737.

Umanath, M, R Balasubramaniam, and R Paramasivam. 2018. Millets' consumption probability and demand in India: an application of Heckman sample selection model. *Economic Affairs 63*(4): 1033-1044.

Vasileska, A, and G Rechkoska. 2012. Global and regional food consumption patterns and trends. *Procedia-Social and Behavioral Sciences* 44: 363-369.

Von Braun, J, H De Haen, and J Blanken. 1991. *Commercialization of agriculture under population pressure: Effects on production, consumption, and nutrition in Rwanda* (Vol. 85). International Food Policy Research Institute. Washington, D.C.

Wang, Y, C Wang, and S Pan. 2011. *The impact of nonfarm activities on agricultural productivity in rural China*. Selected paper prepared for presentation at the Agricultural and Applied Economics Association's 2011 AAEA and NAREA joint annual meeting, Pittsburgh, PA. (No. 321-2016-10791). Retrieved from https://core.ac.uk/download/pdf/6551338.pdf

Yen, S T, and J Rosinski. 2008. On the marginal effects of variables in the log-transformed sample selection models. *Economics Letters* 100(1): 4–8.