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Farm Size and Productivity – Empowering Marginal Farmers for Cultivating Prosperity

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Farm Size and Productivity – Empowering Marginal Farmers for Cultivating Prosperity

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For entrenching India's future food security it would be critical to boost farm productivity, given the projected expansion in demand for food due to increase in the country's population and per-capita income by 2047, amidst shrinking availability of cultivable land reflecting competition from urbanisation and industrialisation, and growing intensity and frequency of climate shocks which could disrupt and impair the food supply situation. In view of the growing empirical evidence over time that small sized farms are more productive in India, land consolidation, an important component of land reforms, has not been pursued vigorously, even as the average farm holding size has continued to shrink from 2.28 hectare in 1970-71 to 0.7 hectare in 2021-22. Using data from the Situation Assessment Survey (2018-19) and NABARD's All-India Rural Financial Inclusion Survey (NAFIS:2021-22), this paper finds that marginal farms remain more productive (in terms of per hectare farm output and income from cultivation), but the share of non-farm income in average monthly total income is high for small and marginal farmers, indicating their feeble dependence on farm income for livelihood. For realising a productivity-led augmentation of farm income, therefore, a multi-pronged policy thrust would be warranted. First, recognising that both survey findings point to relatively lower access for marginal farmers to various available policy enablers, such as kisan credit card (KCC) and institutional credit, crop insurance, soil health card, and collectivisation initiatives to improve the bargaining power of farmers in the form of farmer producer organisations (FPOs) and self-help groups (SHGs), a targeted approach to benefit marginal farmers may be adopted while implementing these policy interventions. Cross-sectional regression results using unit level data from NAFIS:2021-22 show that such policy enablers induce a positive and statistically significant influence on farmers' income from cultivation. Second, to raise productivity through farm mechanisation, either farm equipment suitable for use in small sized farms need to be developed, or shared ownership and use of modern farm machinery may be promoted through FPOs, SHGs and cooperatives. Third, the scope for raising farm size through land consolidation, wherever feasible, may be explored. A cross-sectional regression analysis using unit level data from NAFIS 2021-22 suggests a threshold farm size of 1.65 hectare, and land consolidation to raise the average farm size up to this level can induce notable improvement in farmers' income from cultivation.

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Introduction

Productivity growth is the harbinger of economic prosperity, which requires strategic action plans to climb the "technology ladder" and embrace waves of structural reforms. As noted by Krugman (1994) "Productivity isn't everything, but, in the long-run, it is almost everything". Factor accumulation based growth strategies tend to encounter the challenge of diminishing returns, and therefore, productivity growth becomes crucial for lifting economies to higher levels of prosperity (World Bank, 2024). Globally, improvement in agricultural productivity has been the primary means for assuring that the needs of a growing population has not outstripped the capacity of the world's resources to supply food (USDA, 2025). In the union budget, 2024-25, enhancing productivity and resilience of agriculture was rightly set as one of the nine priorities for the pursuit of "Viksit Bharat". Raising farm productivity will be essential for safeguarding India's future food security and overall economic prosperity, and for achieving three interrelated goals – higher income for the farmers; low and stable food inflation for the consumers; and low cost and uninterrupted supply of farm inputs to the non-farm producers.

Several factors could often depress farm productivity in a country, such as low quality/high cost of and limited access to farm inputs (seeds, fertilisers, credit, farm machinery, pesticides, electricity, water); pre-harvest challenges like use of unscientific methods of production, pest attack and disease, wrong crop selection from the stand point of soil quality and climatic conditions, and access to irrigation; and post-harvest hassles like transportation and storage losses, inadequate market access leading to unremunerative prices, and insufficient processing and focus on quality, value addition, and food safety standards that limit the export prospects. One of the widely debated factors impeding productivity growth in agriculture in India has been the small size of the farms – productivity gains from mechanisation can accrue when the land holding size is more than 10 hectares, and mechanisation is not a viable option for small and marginal farmers (NITI Aayog, 2022). Small farming in India is both a symptom and a cause of under-development – consolidating farm size to an average of 24.5 acres could increase agricultural production by 42% (Foster and Rosenzweig,

2022). Small and fragmented land holdings impede farm mechanisation (CACP, 2025); land fragmentation is a sign of an underdeveloped agricultural system (Jiang et al., 2022).

The farm size related risks to farm productivity could be sensed from the pace of land fragmentation that India has witnessed since the 1970s. As highlighted by Dev (2020), the average farm holding size has declined from 2.3 ha in 1970-71 to 1.08 ha in 2015-16 (as per agricultural census data). The Situation Assessment Survey (SAS, 2018-19) and NABARD's All India Rural Financial Inclusion Survey (NAFIS, 2021-22) show that the average operational holding size has dropped further to 0.558 ha and 0.7 ha, respectively. The minimum threshold farm size that could generate enough income to support average monthly consumption expenditure of farmer households is less than 1 ha in a majority of the states, which is about the average actual size of operational holdings (Sharma and Mallik, 2022). But a large segment of agricultural households possess land which is less than the national average level of farm size. Marginal farmers accounting for 68.5% of total number of farm holdings in the country with a share of 24% of total operated land had an average land holding size of just 0.38 ha in 2015-16. Small farm size poses several challenges, as smallholders have low marketable surplus, poor holding capacity and hence face the risk of distress sales, have low bargaining power and incur higher transaction costs in marketing their produce (Manjula, 2021). Smallholders may still be efficient, but the returns that they generate are woefully low, threatening their sustainability (Mishra and Singh, 2021). Policies for land consolidation along with land development activities are, therefore, needed to tackle the challenge of the low average size of holdings (Dev, 2020).

The farm size and productivity relationship has been an issue of animated debate in India since the time an inverse relationship was propounded by Sen (1962), *i.e.*, small farms are more productive. Das (2021) encapsulates the essence of this rich debate, drawing on key relevant literature available on the subject. In the pre-green revolution stage, small farmers clearly had the advantage of intensive use of human and bullock labour. In the post-green revolution period, however, large farms started gaining the advantage of scale economies and mechanisation. The driving force behind the relationship – inverse or otherwise – has been human efforts *versus* adoption of modern cropping practices. With the widespread dissemination of modern cropping practices, however, the initial advantages of green revolution for large farms would

have dissipated, pointing to no scale advantage or disadvantage, *i.e.*, scale neutrality of farming in India (Mishra and Singh, 2021). Chand *et al.*, (2011) emphasised in this context that small farms don't lag behind others in adoption of improved technology, fertiliser and irrigation, and that the superior performance of small farms has not been dulled by advances in technology. They concluded that any move towards increasing the farm size on the ground that small farms are economically non-viable may adversely affect productivity and growth of Indian agriculture. They nevertheless recognised that at the prevailing level of productivity, three fourths of smallholders cannot meet their livelihood from farm income alone, and therefore, either land to man ratio should improve (which will be possible when a sizable segment of smallholders move out of agriculture) or alternative sources of employment and income should be provided to them. Both SAS (2018-19) and NAFIS (2021-22) show that for small and marginal farmers, the share of non-farm income has increased considerably relative to income from cultivation; and the challenge of land fragmentation has only aggravated further.

In terms of the needed policy response, thus, there are two broad views on how to raise farm productivity by having a policy stance based on desirable farm size, *ceteris paribus*. First, land consolidation, say through voluntary collectivisation, and second, no deliberate attempt to increase the average farm size, but improve access to inputs and technology that can sustain the productivity edge of small farms and also enhance opportunities for augmented non-farm income for them. This paper, recognizing the critical role of productivity to the future of India's food security and rural economic prosperity, revisits the farm-size productivity debate using data from SAS 2018-19 and NAFIS 2021-22, with the aim to propose appropriate policy changes. Section II presents a snapshot of available facts on farms size and productivity in India. India's farm productivity is assessed in the global context in Section III, to examine whether dominance of small farms has been a cause of any comparative disadvantage for India. Using cross-sectional regression models, and NAFIS 2021-22 unit level data, factors that influence crop income, including farm size, are examined in Section IV. Applying a threshold level search procedure to cross-sectional data, the desirable size of land holding for India is explored. Section V discusses policy options available to raise farm productivity, given the dominance of small and marginal land holdings in the country. Concluding observations and the way ahead in terms of warranted policy changes are set out in Section VI.

II. Farm Size and Productivity in India – Some New Facts from NAFIS

Rising population, land ceiling laws that involved redistribution of land exceeding the ceiling, and inheritance laws that result in allocation of land owned by parents among wards have contributed to the rising trend of land fragmentation in India. According to a Rajya Sabha's written answer to the unstarred question number 119 (dated March 11, 2016), farm size is classified in India as marginal (less than 1 ha), small (1 ha and above but less than 2 ha), semi-medium (2 ha and above but less than 4 ha), medium (4 ha and above but less than 10 ha), and large (10 ha and above). Since the first agricultural census conducted in 1970-71, the number of farms has more than doubled from 7.1 crore in 1970-71 to 14.6 crore in 2015-16 (Table 1). During the corresponding period, the number of marginal holdings increased from 3.62 crore (51% of total no of holdings) to 10.0 crore (68.5% of total number of holdings). Their share in total operated area increased from 9% in 1970-71 to 24% in 2015-16, but their average farm size fell marginally from 0.4 ha to 0.38 ha during the corresponding period. In view of the large number of marginal holdings, productivity growth of such farms will be critical for raising their per-capita income, notwithstanding the rising role of non-farm income for rural agri households and fiscal transfers (from centre and states) that supplement their income. With India's population expected to rise further to 1.6 billion in 2047 (Lancet, 2020), and given the assessment that per capita income must increase 8 folds by then for India to become an advanced economy (NITI Aayog, 2024), productivity would have to be the focus across all key sectors of the economy, and in agriculture it must embrace all farmers irrespective of farm size.

While the census data provide information on how the average farm size across size groups has changed over time since 1970-71, comparable data on farm income and output is available only since 2002-03 when the first Situation Assessment Survey (SAS) of Agricultural Households and Land and Livestock Holdings of Households in Rural India was conducted. As per SAS data, the average area owned per household has continued to decline (as observed also from the census data), but the average levels are comparatively much lower (Table 2).

Table 1: Farm Size Group Wise Land Holdings

	1970-71	1976-77	1980-81	1985-86	1990-91	1995-96	2000-01*	2005-06*	2010-11	2015-16	
Size Groups	Number of Holdings (in '000)										
	1970-71	1976-77	1980-81	1985-86	1990-91	1995-96	2000-01*	2005-06*	2010-11	2015-16	% share (in 2015-16)
Marginal (0-1 ha.)	36200	44523	50122	56147	63389	71179	75408	83694	92826	100251	68.45
Small (1-2 ha.)	13432	14728	16072	17922	20092	21643	22695	23930	24779	25809	17.62
Semi-Medium (2-4 ha)	10681	11666	12455	13252	13923	14261	14021	14127	13896	13993	9.55
Medium (4-10 ha.)	7932	8212	8068	7916	7580	7092	6577	6375	5875	5561	3.80
Large (> 10 ha.)	2766	2440	2166	1918	1654	1404	1230	1096	973	838	0.57
All Sizes	71011	81569	88883	97155	106637	115580	119931	129222	138348	146454	100
Size Groups	Operated Area (in '000 ha.)										
	1970-71	1976-77	1980-81	1985-86	1990-91	1995-96	2000-01*	2005-06*	2010-11	2015-16	% share (in 2015-16)
Marginal (0-1 ha.)	14599	17509	19735	22042	24894	28121	29814	32026	35908	37923	24.03
Small (1-2 ha.)	19282	20905	23169	25708	28827	30722	32139	33101	35244	36151	22.91
Semi-Medium (2-4 ha)	29999	32428	34645	36666	38375	38953	38193	37898	37705	37619	23.84
Medium (4-10 ha.)	48234	49628	48543	47144	44752	41398	38217	36583	33828	31810	20.16
Large (> 10 ha.)	50064	42873	37705	33002	28659	24160	21072	18715	16907	14314	9.07
All Sizes	162318	163343	163797	164562	165507	163355	159436	158323	159592	157817	100
Size Groups	Average farm size (in ha.)										
	1970-71	1976-77	1980-81	1985-86	1990-91	1995-96	2000-01*	2005-06*	2010-11	2015-16	
Marginal (0-1 ha.)	0.4	0.39	0.39	0.39	0.39	0.4	0.4	0.38	0.39	0.38	
Small (1-2 ha.)	1.44	1.42	1.44	1.43	1.43	1.42	1.42	1.38	1.42	1.4	
Semi-Medium (2-4 ha)	2.81	2.78	2.78	2.77	2.76	2.73	2.72	2.68	2.71	2.69	
Medium (4-10 ha.)	6.08	6.04	6.02	5.96	5.9	5.84	5.81	5.74	5.76	5.72	
Large (> 10 ha.)	18.1	17.57	17.41	17.21	17.33	17.2	17.12	17.08	17.38	17.07	
All Sizes	2.28	2	1.84	1.69	1.55	1.41	1.33	1.23	1.15	1.08	

Note: The Eleventh Agriculture Census (2021-22) was launched on 28th July 2022. The 2015-16 census results were released in August 2019.

Table 2: Average Size of Household Land Ownership

	Average area owned (ha) per household	% of landless households	Average area owned (ha) per household excluding landless households
SAS 2002-03	0.725	10.0	0.806
SAS 2012-13	0.592	7.4	0.639
SAS 2018-19	0.512	8.2	0.558

Source: MoSPI (SAS rounds)

For any farm productivity analysis using SAS data, it may be kept in perspective that SAS 2012-13 and SAS 2002-03 are not strictly comparable because the latter used a definition of farmer as "a person who operates some land and is engaged in agricultural activities during the last 365 days", whereas the former used the concept of agricultural household as one who received value of produce of more than Rs. 3,000 from agricultural activities. For SAS 2018-19, an agricultural household was defined as a household receiving value of produce of more than Rs. 4,000 from agricultural activities (*e.g.,* cultivation of field crops, horticultural crops, fodder crops, plantation, animal husbandry, poultry, fishery, piggery, bee-keeping, vermiculture, sericulture, *etc.*), and having at least one member self-employed in agriculture either in the

principal status or in subsidiary status during last 365 days (Source: SAS 2018-19). SAS 2012-13 and 2018-19 are, therefore, relatively more comparable.

Productivity, as assessed in terms of compound annual growth rate (CAGR) of net income from cultivation, shows that medium and large farms exhibited higher growth between SAS 2002-03 and SAS 2012-13 than small and marginal farmers. Between SAS 2012-13 and SAS 2018-19, large farms continued to outperform, but lower marginal category farm size did better than small and medium sized farms (Table 3). Thus, while farm size of more than 10 ha is clearly more productive, low marginal size (0.01 to 0.40) category appears to have not only witnessed improved productivity over time but also remained relatively more productive than other categories (excluding large land holdings).

Table 3: Farm Size-wise Growth in Income from Cultivation (Compound Annual Growth Rate, in %)

	SAS 2012-13 over SAS 2002-03		**SAS 2018-19 over SAS 2012-13**	
Size class of land possessed (ha)	**Net Receipt from Cultivation**	**Total Income**	**Net Receipt from Cultivation**	**Total Income**
Near Landless< 0.01	2.4	4.4	34	10
Lower Marginal 0.01 - 0.40	0.8	1.7	5.1	10.9
Upper Marginal 0.41 - 1.00	2.5	3.1	2.8	8.5
Small 1.01 - 2.00	2.2	3.2	3.4	7.6
Semi-medium2.01 - 4.00	2.5	3.4	3.9	7.1
Medium 4.01 -10.00	4.3	4.9	3.4	5.7
Large 10.00 +	7.2	7.2	7.7	9.1
All Sizes	4	3.5	2.6	7.9

Note: CAGR for 2012-13 over 2002-03 are from Mishra and Singh (2021). CAGR for 2018-19 over 2012-13 are from data at Annex Table 1a and 1b. Of the total operational holdings in 2018-19, 84% were for crop production only, and 6% for crop production as well as farming of animal/fishery, and therefore net income from cultivation is the appropriate indicator to assess productivity in the context of farm size. Average monthly income from cultivation is net of 'paid out expenses' and, therefore, could work as rough proxies for productivity. While most SAS tables have six-fold classification, with less than 0.002 ha category considered as landless, the classification used here, and related data are taken from Table 23A of SAS 2018-19 and Table 12 of SAS 2012-13.

For a meaningful comparative assessment of farm size wise productivity, it is important to estimate net cultivation income and output on a per hectare basis, as in Chand *et al.*, (2011). Since the SAS report does not provide average size of holding for each farm size category, and the corresponding average values for output, costs, and net income from cultivation, unit level data are used from SAS 2018-19 to estimate output and net income per hectare for different farm sizes. Though average output for households increases progressively with farm size (showing a positive relationship between farm size and farm output), average per hectare output decreases progressively with farm size (corroborating the inverse relationship), with per hectare output at Rs. 96,711 for land holdings of 0.01 to 0.40 hectare significantly higher than average output for other farm size categories (Table 4). The assessment based on per hectare output is corroborated by per hectare net income from cultivation (which is output adjusted for paid out cultivation related expenses). While for farm holding sizes of 0.01 to 0.4 ha the average net income from cultivation per hectare is Rs. 12, 171, for the remaining farm size categories the average incomes are substantially lower. The observed higher productivity of marginal farmers highlights that, if access to inputs and technology for the lower marginal farmers category (with land holding of 0.01 - 0.40 ha) could be raised, by drawing relevant feedback from SAS 2018-19 on the type of services that they prefer and use (Table 5), that could help enhance overall farm productivity.

Table 4: Farm Size Wise Output and Net Income Per Hectare

Farm Size (ha)	% of Households	Average No. of members in HH (HH Size)	Average size of land owned and possessed (ha)	Output Value (Rs.)		Net Income from Cultivation (Rs.)	
				Per Household	Per Ha	Per Household	Per Ha
0.01-0.4	24	4.15	0.08	7,350	96,711	925	12,171
0.41-1.0	17	4.67	0.65	15,422	23,726	2,535	3,900
1.01-2.0	15	4.69	1.39	28,475	20,485	5,140	3,698
2.01-4.0	24	4.90	2.60	47,928	18,434	9,257	3,560

4.01-10	16	5.22	5.54	95,833	17,298	18,595	3,356
>10	3	5.45	16.32	2,63,199	16,127	55,666	3,411

Note: This table is generated from SAS 2018-19 Unit level data, which has missing values for some households under certain heads, and therefore, the overall average numbers derived here may not tally with the consolidated numbers reported in SAS.

If farmers could have better information and access to modern cropping practices, that may increase productivity even when the farm size is small. It appears that close to half of the agricultural households do access technical advice/services from some source or the other, and among those who access such advice/services, close to 90 per cent actually adopt, which may explain why small farms are found to be productive (Table 5). What emerges from SAS 2018-19 data, however, is that progressive farmers, input dealers and electronic media are the key sources of technical advice providers for the farmers, whereas very few seem to be benefiting from Krishi Vigyan Kendras (KVKs), agricultural universities/colleges, farmer producer organisations (FPOs), Agri clinics and business centres, and NGOs. If these information and technical services are provided more diligently, any small farm size constraint to future productivity growth in Indian agriculture could be effectively addressed.

Table 5: Percentage of Agricultural Households Accessing Technical Advice from Different Sources

Source of Technical Advice	**July 2018-Dec 2018**		**Jan 2019-June 2019**	
	% of Agri households accessing technical advice	% adopted advice among those who accessed advice	% of Agri households accessing technical advice	% adopted advice among those who accessed advice
Progressive farmers	22.8	92.1	20.3	91.0
Input dealers	19.9	93.3	19.1	92.4
Govt. Extension agent/ATMA	3.1	83.4	1.5	86.2
Krishi Vigyan Kendra (KVK)	1.3	80.4	0.5	72.0
Agri University/College	0.3	79.9	0.2	73.8
Private Commercial agents	1.2	74.6	0.9	85.7
Veterinary department	6.6	89.5	6.8	90.6

Cooperatives/Dairy Cooperatives	2.7	89.5	1.8	90.1
Farmer Producer Organisations (FPOs)	0.5	79.0	0.3	87.6
Private Processors	2.1	86.5	2.3	90.2
Agri Clinics & Agri Business Centres	0.5	70.9	0.3	90.5
NGOs	0.6	70.3	0.2	68.5
Kisan Call Centres	1.5	69.5	0.7	72.0
Print Media	5.3	67.6	4.1	65.4
Radio/TV/other electronic media	13.2	65.4	8.2	61.7
Smart phone app based information	1.2	75.5	0.8	62.8
Any source	48.7	89.8	42.2	89.5
Source: SAS 2018-19				

NABARD's All India Rural Financial Inclusion Survey (NAFIS) provides additional information to examine the relationship between farm size and productivity, and for a more recent period compared with the SAS. When NAFIS 2021-22 data are compared with NAFIS 2016-17, the CAGR of income from cultivation turns out to be the maximum for farm holding size of 1.01-2.0 ha, and the CAGR for farm holding sizes of both "0.01-0.40 ha" and "greater than 2 ha" are lower (Table 6). Unlike SAS data, NAFIS data show that for farm size category of "0.01 to 0.4 ha" the CAGR of total income from all sources is maximum, signifying the importance of non-cultivation income for such households (Annex Table 2a and 2b present data on all different sources of income). When NAFIS data on income from cultivation are seen in terms of per hectare of land, land holding sizes of less than 0.01 ha and 0.01-0.40 ha again emerge as the most productive, similar to the results obtained using SAS data (Table 7). The disproportionately high numbers for less than 0.01 ha size class could be due to the magnifying effect of statistically converting symmetrically a small output/income on a per hectare basis, whereas in practice this level of outcome may be difficult to achieve. Using the estimated per hectare level for the "0.01 to 0.4 ha" category, therefore, could be more appropriate, and this size class clearly shows higher crop income and output relative to other larger size classes.

Table 6: CAGR of Average Monthly Income of Agricultural Households						
Size Classes/ Sources of Income	<0.01 ha	0.01-0.40 ha	0.41-1.00 ha	1.01-2.00 ha	>2.00 ha	All Agri Households
Cultivation	-16.8	3.8	10.9	14.1	11.3	7.3
Total income from all sources	6.4	11.3	10.6	10.6	7.6	8.9
Note: CAGR numbers are estimated from base data reported in Annex Table 2a and 2b.						

Following the approach adopted in SAS, an agricultural household in NAFIS 2021-22 is defined as one receiving value of produce of more than Rs. 6,500 per annum from agricultural activities (*e.g.,* cultivation of field crops, horticultural crops, fodder crops, plantation, animal husbandry, poultry, fishery, piggery, beekeeping, vermiculture, sericulture, *etc.*) with at least one member self-employed in agriculture during the reference agricultural year (2021-22). In NAFIS 2016-17, the income threshold was set at Rs. 5,000 per annum. While income from both cultivation and allied activities are used for the purpose of classifying households as agri *versus* non-agri, given the focus of this study on farm size and productivity, only income and output from cultivation are used in the analysis.

Table 7: Farm Size-Wise Per Hectare Crop Income and Output (Rupees)		
	Average Monthly Income from cultivation (per Household)	**Average Monthly Income from cultivation (per Hectare)**
<0.01 ha	225	39,518
0.01-0.40 ha	1,792	16,367
0.41-1.00 ha	4,193	6,837
1.01-2.00 ha	8,684	6,297
> 2.00 ha	12,930	4,010
All Size Classes (Agri Households)	4,476	10,075
Source: NAFIS 2021-22		

While examining the relationship between farm size and productivity, it is important to also recognise that small farms may be more productive, in terms of per hectare agri output or income from cultivation, but the share of income from cultivation as percentage of their total monthly income may be very low. As could be

seen from Annex Table 2b, for farm holding sizes of less than 0.01 ha and 0.01 to 0.04 ha, the share of monthly income coming from cultivation is only 2% and 16%, respectively, as against 52% and 61% for farm sizes of 1.01 to 2 ha and above 2 ha, respectively. Livestock and wages are the dominant sources of income for rural agri households that possess less than 0.4 ha of land.

It is also found from NAFIS data that marginal farms (as revealed by them through the survey), particularly those with less than 0.4 ha of land (accounting for 37% of total rural agri households) have relatively less access to kisan credit cards (KCC) for availing agricultural credit with interest rate subventions, crop insurance, and collectivisation schemes meant to empower them, such as self help groups (SHGs), farmer producer organisations (FPOs), custom hiring centres (CHCs) and joint liability groups (JLGs) (Table 8). While the situation would have improved since the time when the survey was conducted, but it is evident that many of the rural development schemes could be better targeted to cover all marginal farmers, and thereby empower them to improve farm productivity further, which in turn could raise their income from farming. It may be noted that even SAS (2018-19) had reported similar asymmetry in access to policy enablers, with marginal farmers having relatively less access to KCC, crop insurance, membership of FPO, soil health card and animal health card (Table 9).

Table 8: Farm Size-Wise Access to Productivity Enhancing Services

NAFIS: 2016-17

Size Classes	% share of Agri HH	% of HH having a KCC	% of Agri HH having Crop Insurance	% of Agri HH with at least 1 member associated with an SHG	Share of Credit from Institutional Sources in Total Credit (%)
<0.01 ha	6	1.2	0.1	26.9	70.9
0.01-0.40 ha	31	5.9	1.5	24.3	58.8
0.41-1.00 ha	30	10.8	5.1	22.7	69
1.01-2.00 ha	20	14.1	10.8	17.1	79.9
> 2.00 ha	13	23.8	8.0	17.1	78.2
All Size Classes	100	10.5	6.9	21.6	72.3

NAFIS: 2021-22					
Size Classes	**% share of Agri HH**	**% of HH having a KCC**	**% of Agri HH having Crop Insurance**	**% of Agri HH with at least 1 member associated with an SHG**	**Share of Credit from Institutional Sources in Total Credit (%)**
<0.01 ha	6	9.5	0.7	26	84.6
0.01-0.40 ha	38	30.1	4.1	28	80.6
0.41-1.00 ha	33	54.3	9.3	31	86.7
1.01-2.00 ha	15	62.7	14.5	23	88.7
> 2.00 ha	8	59.1	20.5	19	91.7
All Size Classes	100	44.1	10.8	27.1	86

Table 9: Agricultural Households with Access to Policy Enablers (SAS:2018-19)

Size classes of land possessed (ha)	Per 1000 of Agricultural Households					
	Bank Account	Membership in registered farmers' organisation	Kisan Credit Card	Crop Insurance under PMFBY	Soil Health Card	Animal Health Card
<0.01	939	1	17	20	11	24
0.01 - 0.40	976	31	97	15	7	4
0.41 - 1.00	977	38	194	56	14	4
1.01 - 2.00	987	50	264	120	23	9
2.01 - 4.00	989	62	332	185	25	9
4.01 - 10.00	991	66	409	246	38	14
10.00+	983	42	487	307	63	38
All sizes	980	41	191	71	15	6

Source: SAS (2018-19) (Estimated number of households given in this Table are design-based estimates and may be used as control totals for combining and arriving at rates and ratios. These figures are not intended for providing the number of households).

III. Crop Land Productivity - A Cross-Country Comparison

For any analytically sound cross-country productivity comparison, the information used for comparison and their interpretation becomes critical. For example, India's share in total global workforce engaged in agriculture and allied activities is high at 25.4%, while its share in global agriculture sector gross value added (GVA) is 12.5% and in total world crop production is 12.7%, which would indicate that labour productivity (or output per unit of labour) is low in India (FAO, 2024). As per data from the FAO Yearbook (2024), as against India's gross value added from agriculture (in 2022) at USD 480.03 billion, which was the outcome of 226.06 million labour force working in agriculture, Europe and the USA together engaged only 20.68

million workforce (*i.e.,* less than one tenth) to generate higher agricultural value added of USD 503.07 billion. China's value added from agriculture was as high as USD 1,278 billion for which it employed 169.88 million workforce.

When the same comparison is done with "crop land use" as the focus rather than employment in agriculture, it turns out that India's agri gross value added and farm output per million hectare of land is higher than the global average, and even higher than that of Europe and the USA (Table 10 and 11). India's crop land productivity, however, lags the average productivity levels achieved in Asia, led by China, Indonesia, Vietnam and Thailand. What is particularly relevant to the debate on farm size and productivity relationship from this cross-country comparative information is that many of these Asian countries also have small average land sizes, unlike in the USA, Europe, Canada and Australia, but smaller average size of land can deliver higher productivity.

Table 10: India's Crop Land Productivity in a Global Context (in 2022)

	Value Added (Agri and allied) (USD billion)	Share of Countries in World Agri Value Added (%)	Primary Crop Production (Million Tonnes)	Share in World Primary Crop Prod (%)	Crop Land (000 ha)	Share in World Crop Land	Value Added per Ha Land (USD Billion)	Crop Prod per Ha Land (mln tonnes)
World	**3830.04**	**100.00**	**9608.6**	**100.00**	**1573.35**	**100.00**	**2.43**	**6.11**
Africa	449.09	11.73	1033.03	10.75	304.75	19.37	1.47	3.39
Americas	483.4	12.62	2507.31	26.09	369.32	23.47	1.31	6.79
Asia	2522.83	65.87	4877.69	50.76	576.91	36.67	4.37	8.45
Europe	322.32	8.42	1067.12	11.11	288.3	18.32	1.12	3.70
China	1278.45	33.38	1885.05	19.62	128.36	8.16	9.96	14.69
Indonesia	142.37	3.72	447.14	4.65	45.39	2.88	3.14	9.85
Egypt	46.18	1.21	92.46	0.96	4.06	0.26	11.37	22.77
Mexico	42.97	1.12	140.54	1.46	21.91	1.39	1.96	6.41
Nigeria	122.19	3.19	225.87	2.35	44.64	2.84	2.74	5.06
USA	180.75	4.72	675.77	7.03	154.74	9.84	1.17	4.37
Vietnam	42.7	1.11	108.6	1.13	11.67	0.74	3.66	9.31
Turkey	66.41	1.73	128.94	1.34	23.86	1.52	2.78	5.40
Thailand	39.27	1.03	205.82	2.14	22.7	1.44	1.73	9.07
Canada	32.83	0.86	108.19	1.13	38.52	2.45	0.85	2.81
Brazil	87.69	2.29	1075.35	11.19	63.4	4.03	1.38	16.96
India	**480.03**	**12.53**	**1229.83**	**12.80**	**168.05**	**10.68**	**2.86**	**7.32**

Source: FAO Yearbook, 2024

Table 11: India's Labour Productivity in Agriculture in a Global Context				
	Employment in Agriculture (million persons)	Share in World Employment in Agri (%)	Value Added per Million Employment (USD Billion)	Crop Produced per Million Employment (Mln tonnes)
World	**892.44**	**100.00**	**4.29**	**10.77**
Africa	238.14	26.68	1.89	4.34
Americas	43.09	4.83	11.22	58.19
Asia	591.85	66.32	4.26	8.24
Europe	18.01	2.02	17.90	59.25
China	169.88	19.04	7.53	11.10
Indonesia	39.04	4.37	3.65	11.45
Egypt	5.7	0.64	8.10	16.22
Mexico	7.18	0.80	5.98	19.57
Nigeria	26.81	3.00	4.56	8.42
USA	2.67	0.30	67.70	253.10
Vietnam	18.43	2.07	2.32	5.89
Turkey	5.19	0.58	12.80	24.84
Thailand	12.33	1.38	3.18	16.69
Canada	0.26	0.03	126.27	416.12
Brazil	8.62	0.97	10.17	124.75
India	**226.06**	**25.33**	**2.12**	**5.44**

Source: FAO Yearbook, 2024

Besides the aggregate level comparison of productivity, it is also important to assess crop-wise yield levels, as the future of India's food security would require productivity-led higher supply of food items covering the entire consumption basket. As highlighted by NITI Aayog (2024), in view of the limited scope for bringing more area under cultivation, and the possibility of diversion of agricultural land for other non-farm activities in future, intensive cultivation (multiple cropping in a year) and technology adoption would be critical. It highlighted India's yield gaps relative to 20 major producing countries, which is 24-54% less than the country's potential yield, and 33-74% less than the average yields of five major producing countries. India's yield gaps relative to the country's own demonstrated yield potential as well as yield levels achieved in other major producing countries are also highlighted by the CACP (2025). Recent comparative yield positions based on USDA (2025) data also show India's persisting yield gaps relative other major farm producing countries, though its yield

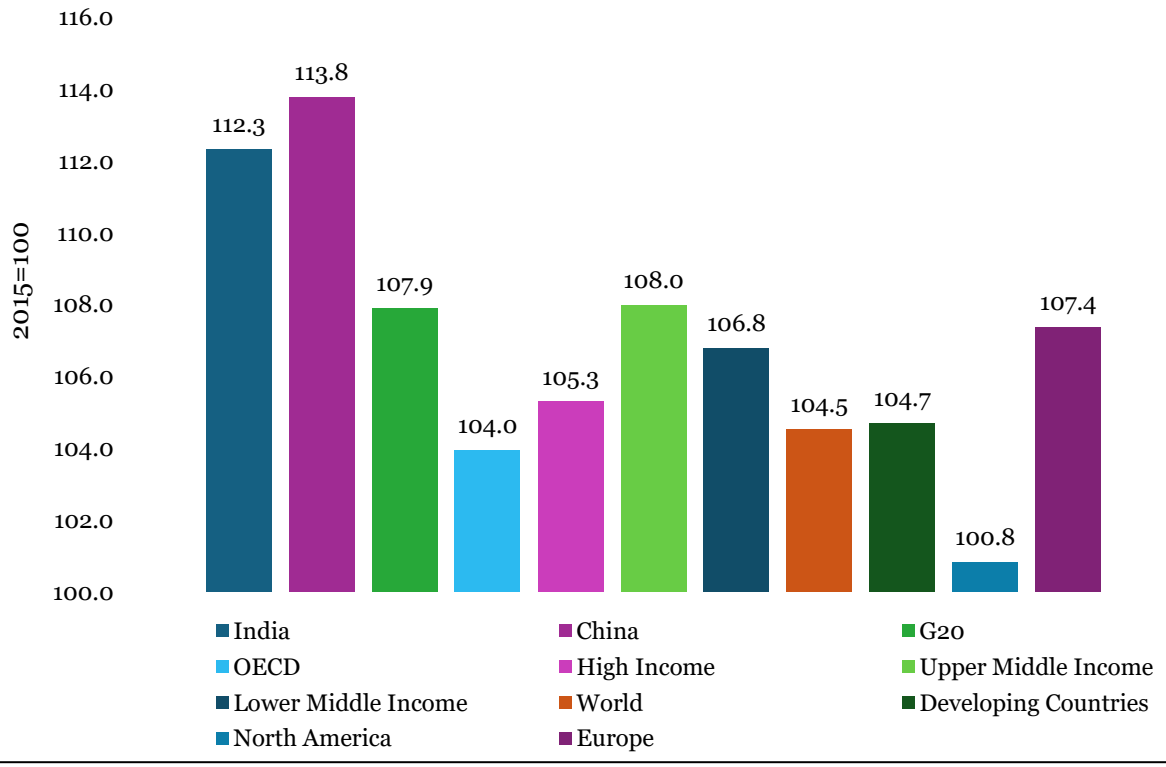
levels are closer to the world average levels (Table 12). Thus, unlike an aggregate level analysis based on overall agri GVA and output, crop level information could be more revealing.

Table 12: Comparative Crop-Wise Yields (2023-24)			
	Yield (Metric tons per hectare)		Yield (Kilograms per hectare)
	Wheat	Rice	Cotton
World	**3.55**	**4.7**	**789**
United States	3.27	8.56	1,008
European Union	5.57	6.19	NA
China	5.78	7.14	2,089
India	**3.52**	**4.32**	**436**
Brazil	2.33	6.58	1,911
Egypt	6.57	8.7	686
Mexico	6.21	NA	1,435
Source: USDA (May 2025)			

As emphasised by USDA (2025), the more relevant concept in any analysis of farm productivity is total factor productivity (TFP) and not yield. Yield per hectare of land is sensitive to use of inputs and adoption of technology. More input use can raise yield. TFP instead captures the efficiency of input use – land, labour, capital, and material, or the average productivity of all inputs combined. Its TFP index (2015=100) can help in comparing India's TFP in agriculture relative to other major economies (Figure 1). Annual time series data for several countries are available since 1961 from this source. Since the base 2015=100 is the same for all countries, the index values for the most recent period (2022) could be used for a cross-country comparison. While India's TFP level in agriculture is close to that of China, it is higher than corresponding levels for all major regions of the world. Using KLEMS data base of RBI, which has annual TFP growth in agriculture since 1981-82, and converting USDA TFP index for India to a common base (1980-81=100), it appears that India's TFP in agriculture has improved gradually and consistently over time (Figure 2), which is often not recognised while looking at either labour productivity (output per unit of labour) or crop yields. From the cross country analysis it may be appropriate to conclude that while more input use to raise yields is one option for India, given the rising sensitivity of countries to green cropping practices and prescriptions like maximum residual limits (MRLs) and no deforestation for cultivation, etc, that could dampen India's agri

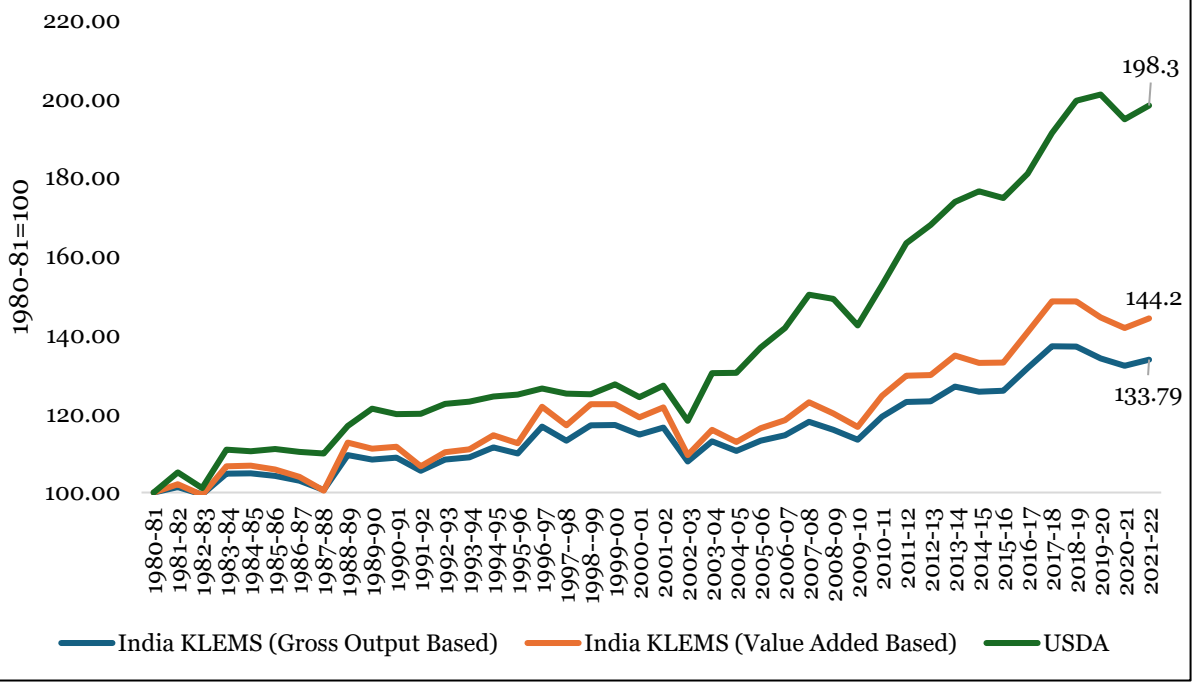
export prospects, adoption of technology and modern cropping practices in small farms to raise TFP could be the preferred path to pursue. Maximizing output while minimising input use would require a TFP focused approach. This would require much greater involvement of Krishi Vigyan Kendras (KVKs), agricultural universities/colleges, Agri clinics and business centres, self-help groups (SHGs), farmer producer organisations (FPOs), custom hiring centres (CHCs), joint liability groups (JLGs) and rural multipurpose cooperative credit institutions at the grassroots level to bridge information gaps and improve access to TFP enhancing cropping practices while safeguarding the interest of small farmers across the entire value chain.

Figure 1: Total Factor Productivity in Agriculture (In 2022 Relative to 2015=100)



Source: USDA, Agricultural Research and Productivity (May 2025)

Figure 2: Total Factor Productivity of Agriculture in India (Index: 1980-81=100)



Source: RBI (KLEMS) and USDA.

IV. Empirical Estimate of Threshold Farm Size for India

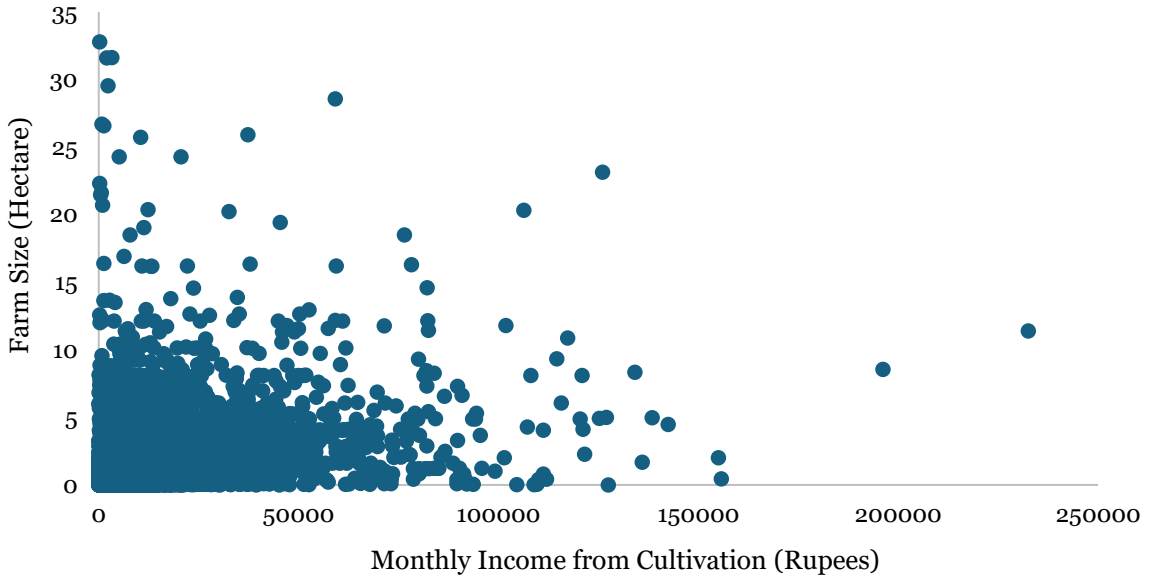
As alluded to in the previous sections, while small farm size may not have been a drag on farm productivity in the past, it is likely to emerge as a constraint in the future, requiring policy emphasis on land consolidation, to raise minimum farm size to a threshold level, at which the potential productivity gains could possibly be maximized. Estimation of threshold farm size is an empirical issue, a prerequisite for which is availability of adequate data on farm holding size and corresponding income earned from cropping. NAFIS 2021-22, given its wide coverage of 59,069 rural agricultural households, provides rich unit level information on income from cropping, farm size and also some of the other determinants of farm income besides farm size, such as access to institutional credit, crop insurance, and collectivization avenues in the form of SHGs/FPOs/JLGs/CHCs. Using this database, the standard cross-sectional threshold estimation regression methodology has been applied to identify the likely threshold level of farm size for India. In the empirical estimates, it may be noted that all factors that may influence crop income are not available in NAFIS 2021-22, and therefore, along with farm size only some of the relevant policy variables are captured in the model. As a result, the focus of analysis in this section is not to capture all the determinants of crop income (or, to have high R^{-2} in the

regression model), but to establish whether the variables of interest are statistically significant and have the right signs so that relevant policy inferences could be drawn from the empirical work.

Threshold regression is used when the relationship between variables is expected to be non-linear, *i.e.*, the behaviour of an outcome variable (such as income from cultivation) is believed to change when the value of a key determinant (say farm holding size) crosses a threshold level. In a grid search process, usually a threshold level is picked from a series of regression equations based on minimum residual sum of squares (RSS) or maximum R^{-2}. When the threshold value is generated as per Hansen (2000), it has the advantage that the non-linear functional form of the model need not be specified and that the threshold value can be determined from the data endogenously (Sengupta *et al*, 2025). Hansen (2000) approach, that is used commonly in cross sectional analysis, requires all explanatory variables to be exogenous, and it has the advantage that the threshold is determined within the model, and not chosen arbitrarily through a search process (Chang *et al.*, 2010). Use of a statistical software package like STATA helps in estimating the threshold directly, yielding coefficients that differ between regions (separated by above and below threshold).

A scatter plot of unit level data on farm size and corresponding farm income for India suggests both (i) a linear relationship, with large deviations, and (ii) likely presence of a non-linear relationship between the two (Figure 3), which is corroborated by the results of cross sectional regression estimates (Table 13). While in the first equation the influence of farm size on crop income is studied, in the second equation, to assess the possibility of non-linearity, square of farm size is used as an additional explanatory variable. Results of equation 2 corroborate the presence of non-linearity in the relationship. This provides leads to explore threshold regression, but before that the influence of policy variables on income from cultivation is also studied. Among the range of policy variables, namely access to KCC and crop insurance, share of institutional credit in total credit, and membership of SHGs/FPOs/JLGs/CHCs, crop insurance and institutional credit emerge as statistically significant determinants of crop income. In view of high collinearity between KCC and institutional credit, only the latter is used in equation 3.

Figure 3: Farm Size and Farm Income



Note: Unit level data indicates presence of outliers/extreme values in the survey data. Most of data points lie within less than 15 ha of farm size and less than Rs.1 lakh monthly income from farming.

Table 13: Cross Sectional Regression Estimates

Income from Cultivation	Equation 1 (Linear)	Equation 2 (Non Linear)	Equation 3 (Linear)	Equation 4 (Linear)
Constant	2216.975* (34.14152)	1354.324* (36.51854)	1931.511 * (67.42762)	900.4723* (69.90926)
Land Holding	2860.424* (24.74102)	4347.537* (35.49747)	3016.248 * (33.86395)	4890.812* (54.63891)
(Land Holding)^2		-149.4339* (2.620143)		
Land Holding Threshold (2.9ha)				-3896.003* (90.53277)
Crop Insurance			1303.71 * (118.3633)	595.3423* (116.4571)
Institutional Credit			4.423699 * (0.7911205)	3.128169* (0.7711526)
Adj R-squared	0.1845	0.2271	0.2034	0.2444

** Indicates significant at 1% level. Figures in parentheses are standard errors.*

A threshold regression model for estimating the threshold value within the model would involve the following specification of the relationship between farm income and farm size:

$Y_i = \beta_1 x_i + \epsilon_i$, if $q_i \leq \gamma$,

$Y_i = \beta_2 x_i + \epsilon_i$, if $q_i > \gamma$,

where:
y_i is farm income (the dependent variable), i means i^{th} farm
x_i is an independent variable,
q_i is the threshold variable (farm size),
γ is the threshold value,
β_1 and β_2 are the regime-specific coefficients, and
ϵ_i is the error term.

This methodology can help in not only identifying the threshold value (γ) but also in estimating regime specific coefficients (β_1 and β_2).

The threshold farm size for India is estimated to be 1.65 hectare (Table 14), which would imply that 90% of agricultural households that have farm size below this threshold could raise their income from cultivation through farm consolidation. While the average monthly income from cultivation for this category is Rs. 3,506 (as per household responses in the survey), for the above threshold 10% farm holdings, the average monthly income from cultivation works out to Rs. 12,658. But, as per the threshold analysis, farm size is particularly significant for below threshold households (with more than three times higher value of the coefficient), *i.e.*, the potential for raising income from cultivation by increasing farm size is high for small and marginal farmers. The empirical results, thus, support the need for land consolidation. Moreover, institutional credit and crop insurance seem to increase income from cultivation for 90% (below threshold) agri households, suggesting the role of institutional credit in facilitating purchase of inputs and capital investment and the role of crop insurance in encouraging risk taking. For the agri households with land holding above the threshold, however, insurance seems to lower income from cultivation, which could point to the moral hazard in terms of disincentivizing farmers to adopt ways to enhance crop resilience because of the comfort of insurance protection.

The alternative approach of a spline regression (Sarel, 1995) was also used, under which the model is estimated iteratively by varying the threshold value in small increments (of 0.1 hectare, for example) across a range of plausible values. The threshold is identified as the value that minimizes residual sum of squares (RSS) (or equivalently, maximizes adjusted R^2), indicating the best fit of the model, for the following model specification:

Income from cultivation = $c + \beta_1$ Land Holding + β_2 Crop Insurance + β_3 Institutional Credit + $\beta_4 D_1$ (Land Holding – threshold) + **ε**

where, D1 is the dummy variable that takes the value of 1 when actual land holding is greater than the threshold and 0 otherwise. While β1 explains the impact of land size on farm income, β4 captures the impact of holding size exceeding the threshold on farm income. When farm size is below threshold, β1 captures the impact of farm size on farm income. However, when farm size is above the threshold, (β1 + β4) give the impact of farm size on farm income. As per this approach, the threshold farm size works out to 2.9 hectare (Figure 4), and the corresponding parameter estimates are presented in equation 4 (Table 13).

Table 14: Estimated Coefficients from Threshold Regression Model

Threshold (Land Holding)	**1.6472663 (Hectare)**	
	Below Threshold	**Above Threshold**
Constant	859.9056 * (76.42082)	8295.066* (272.41)
Land Holding	5076.458 * (87.55414)	1399.946 * (52.12)
Crop Insurance	887.798 * (129.6)	-867.1319 * (270.21)
Institutional Credit	2.029985 * (0.807351)	15.70126 * (2.62)

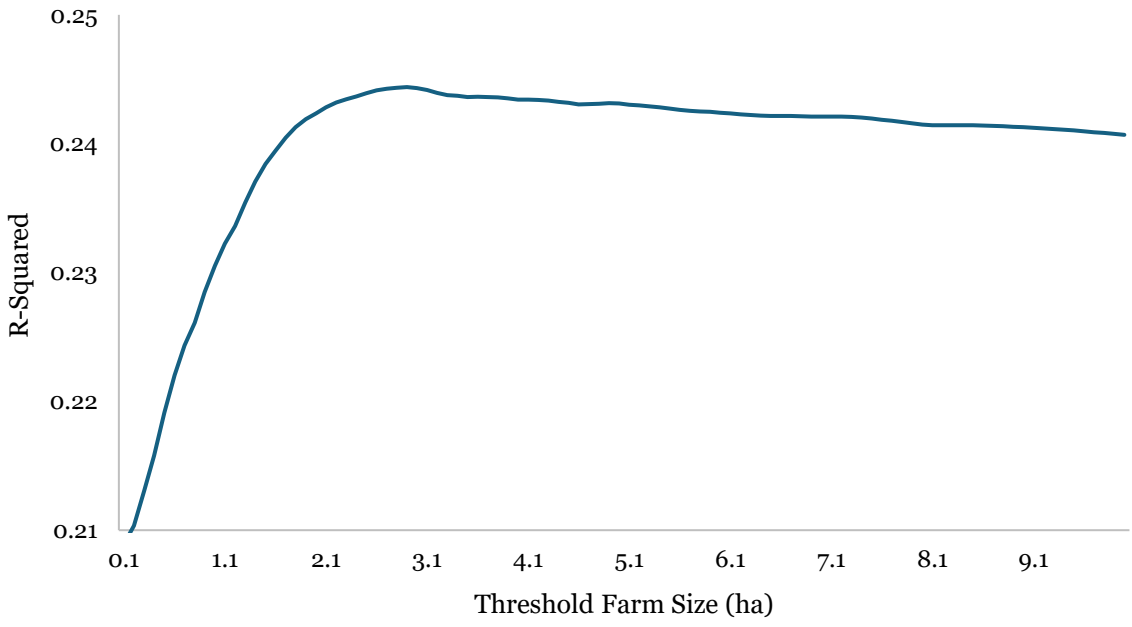
**Indicates significant at 1% level. Figures in parentheses are standard errors.*

The heteroscedasticity-consistent Lagrange multiplier (LM) test statistic of 0.03255 (with a p-value of 0.06), based on 500 bootstrap replications, strongly rejects the null hypothesis of "no threshold".

Note: It may be noted that the threshold assessment is based on total income from cultivation and not income from cultivation per hectare, because, given the average land holding size of 0.08 ha for nearly one fourth of the households, generating per hectare income figures could impart a strong statistical bias to the data.

What one observes from the spline regression estimates is that even after 2.9 hectare farm size (identified as threshold based on maximum R^{-2}), ($\beta_1 + \beta_4$) values remain positive up to farm size of 5.6 hectare and turns negative only thereafter. After 5.6 hectare, while β1 continues to be positive, negative β4 dominates, yielding negative total impact on farm income. Due to lack of consistency between threshold value as per maximum R^{-2} and as per the point of kink in (β1 + β4) values, it may not be appropriate to consider 2.9 hectare as the ideal farm size, notwithstanding the fact that in the literature for India even higher sizes of farm holdings have been recommended as appropriate, as mentioned in the introduction section of this paper.

Figure 4: Threshold Farm Size (Sarel Method)



V. Policy Options to Address Impediments to Spreading Prosperity from Land Fragmentation

Small and marginal farmers, who constitute about 86% of agri households, have to be an integral part of any solution aimed at bolstering India's food security in the future and making farming environmentally more sustainable, given the expected challenges ahead arising from the projected increase in the country's population to 1.6 billion by 2047, an eight fold increase in per-capita income to become an advanced economy – that would increase further the overall demand for food (notwithstanding the expected decline in the share of food in average household consumption), decline in arable land available for agriculture (facing competition for land from

industrialisation and urbanisation), and the unavoidable compulsion of meeting the tightening global green standards to be able to export farm products to some of India's major trading partners. Global experience would suggest that land consolidation and/or mass adoption of smart tech-enabled farming solutions by small farms are the two available major policy options, which need to be promoted in India as part of the medium-term strategy for the farm sector.

Among the key elements of land reforms – abolition of zamindary system, tenancy reforms to avoid exploitation of tenants by landowners, ceiling on land holdings and land consolidation – the last one could be viewed as the most important but an ignored area of reform in India (Munnagi *et al.*, 2020). Farmers can become more competitive when they increase their farm size (Bhogatia, 2025). Globally, it has been assessed that land consolidation and agricultural mechanisation is the future (Zia, 2023) – by 2100 the number of farms could decline by half and the average farm size could double; while agriculture in the early 20th century was labour intensive and hence small farm size remained productive, in the 21st century farm production could be concentrated in a smaller number of large specialised farms, a trend that is already seen in the USA and Western Europe. 70 percent of the literature on the subject supports the negative impact of land fragmentation globally on various measures of farm performance - farm efficiency, agricultural productivity, farm mechanisation, labour efficiency, profitability, crop diversification and cost of production (Aslam, 2025). Since the two major forces causing land fragmentation in India – population growth and the inheritance system – are unlikely to reverse in the near to medium-term, voluntary land pooling, cooperative farming, and incentive-induced land consolidation are the options that could offer small farmers the benefits of economies of scale, better access to technology, and efficient integration with the food supply chain. Land consolidation programmes could be effective only when landowners perceive the benefits and participate, and they must recognise that the land fragmentation trend, unless arrested and reversed, could reduce the plot size to below the threshold level needed for mechanisation (Deininger *et al.*, 2016). Small average size of the farm, with multiple non-contiguous plots, could make farming comparatively less efficient because of loss of land during the formation of plot boundaries, increased travel time between fields that saps energy of farmers, and higher cost of transportation, both for inputs and output.

Besides land consolidation, the other policy option available is last-mile delivery of agtech solutions to small and marginal farmers, recognising the specific nature of support they may require to raise farm productivity. As they are vulnerable to the growing intensity and frequency of climate shocks; have relatively limited access to finance and government benefits, as explained in the previous section based on SAS and NAFIS data; and face the challenge of weak bargaining power while purchasing inputs and selling their produce, the agtech solutions accordingly need to be relevant to appeal to them. Solutions to these problems are already available now because of advances in technology and the country's robust digital infrastructure – drones and sensors could provide early warning weather advisory, real time data on crop health, information on soil conditions and nutrient deficiencies, and detect pests and diseases, while precision equipment could enable economical and judicious use of water, fertilisers and chemical inputs.

The Standing Committee Report (2023), while highlighting that farm mechanisation is critical for increasing agricultural production and productivity, also noted India's relatively lower level of farm mechanisation (47% of agricultural activities) against 60% in China and 75% in Brazil. It also recognised that unless land consolidation takes place, or machine appropriate for use in small holdings is provided, it may remain a challenge to reap the benefits of mechanisation, and it could take about 25 years for India to achieve 75-80% level of farm mechanisation. The Committee had specified areas where policy actions have been launched, such as introduction of custom hiring centres and farm machinery banks to promote shared use of machines; a sub mission on agricultural mechanisation (SMAM) launched in 2014-15 as a single window facilitator for mechanisation of small and marginal holdings, which was merged later with the Rashtriya Krishi Vikas Yojana (RKVY) in 2022; and subsidising 45-50% of the cost of farm equipment to small and marginal farmers for the purchase of tractors, power tillers, combine harvesters, rotavators, rice transplanters, *etc.* The current ongoing pathbreaking work on digitisation of "farm, farmer and farming" through the AgriStack initiative could help in promoting both land consolidation and adoption of appropriate technology in small farms, as it involves creating a farmer registry, where each farmer would have a unique ID enabling digital verification of credentials; information on farmers would be dynamically linked to farm land plot records; the crop sown registry would have real time information on crops being sown and grown on every farm by each farmer; and a

unified farmer service interface (UFSI) would enable interoperability across stakeholders in the agri value chain. The Unique Land Parcel Identification Numbers (ULPIN), Bhu-Aadhaar, would also help in monitoring farm size based farm activity and progress on mechanisation, and hopefully their benefits in terms of impact on output and productivity. AgriStack is expected to improve access to credit, farm inputs, markets for selling the produce, localised market intelligence on weather conditions and cropping practices that could increase crop yields and enhance resilience to climate shocks. The central government has already provided financial incentives to the states under the scheme for special assistance to states for capital investment to undertake land reforms, propelling progress in implementation of AgriStack. Under the recently announced new Viksit Krishi Sankalp Abhiyan, 2000 teams have been formed that will cover all districts of India and create awareness about climate resilient and high yielding varieties and benefits of various government schemes, and it is expected that with scientists and experts from the Indian Council of Agricultural Research (ICAR), KVKs and state-level departments of agriculture, horticulture, animal husbandry and fisheries driving this Abhiyan as core members of each team, last mile delivery of agtech solutions to farms of any size and location would be more feasible now.

While recognising the transformative potential of such tech-led initiatives to raise farm productivity, however, it is also important to be aware of the multiple hurdles that may have to be encountered because of small size of farm holdings. Highlighting the low inclination of farmers in Asia for adoption of agtech (relative to North America and Europe), McKinsey (2023) noted the high cost of adoption, uncertain return on investment (RoI) and unwillingness of farmers to incur the initial expenses for adoption as the key impediments. It also reported that the adoption of agtech is usually higher in larger farms. Agritech Startups, as a result, tend to struggle while scaling up, even after demonstrating good promise at the early stage – after the seed and series A rounds, due to lack of adequate customer base, it becomes difficult for them to raise later-stage funding or go public.

There are also India specific impediments to adoption of agtech, which is evident from the lacklustre response of the farmers to past crop diversification initiatives. The open-ended procurement of rice and wheat at remunerative minimum support prices (MSPs) has been a disincentive for crop diversification (NITI Aayog,

2024). While MSPs are announced for 22 mandated agricultural crops, limited procurement or no procurement in case of the other 20 crops creates uncertainty for the farmers about post-harvest realisation of crop income. Limited and hesitant adoption of agtech in crops where procurement is not assured may hinder in generating the transformative impact of agtech on crop yields. In the case of palm oil, as a specific example, where diversification is necessary for self-sufficiency given the country's high dependence on imports, small farm size seems to be emerging as a major impediment. As highlighted by Gulati and Juneja (2025), oil palm yields (tonnes per hectare) could be 10 times more than mustard, but it takes four-six years to mature and small farmers may not have the capacity to survive income loss over such a long time period, despite the promise of higher long term profits. Pooling of land, in a manner and form that is feasible in Indian conditions, whether through the formation of FPOs and cooperatives or corporate leasing, needs to be explored to achieve the goal of crop diversification. Based on information collected through a survey of farmers (in Hiware Bazaar, Maharashtra, India), Jadhav (2024) examined in detail the challenges to agtech adoption in India and noted that cultural and social barriers make the choice of abandoning traditional farming practices a difficult proposition in India, and scepticism about the effectiveness of new technologies and concerns about data privacy and reliability of digital tools also lead to resistance by the farmers. A survey of agri-startups found fragmentation of land holdings as a major constraint to adoption of new farming techniques in India (Suganthi *et al.*, 2024). Another survey of marginal farmers indicated that while climate-adaptive farming options exist, their dissemination and implementation is inadequate (Venkatesan and Paul, 2024). Thus, while mass adoption of agtech can be a solution to raise productivity in small farms, practical hurdles to tech adoption would require policy focus on land consolidation also, as small farm size can potentially be a constraint to farm productivity in the future, notwithstanding the past evidence of relatively higher productivity of small farms when agriculture was largely labour-intensive and also input intensive, backed by subsidies, which may not be fiscally and environmentally sustainable in the future.

VI. Conclusions

Land fragmentation in India – an outcome of rising population, land ceiling laws and inheritance laws – has not been viewed generally as a major concern yet, because of the proliferating empirical evidence that small farms remain more productive. Distinct ongoing shifts in the structural and micro financial conditions in the economy, however, call for adoption of a different approach to farm size in the future for preserving the country's food security. First, the subsidy-induced input-intensive path pursued in the past for raising crops yields may become increasingly unsustainable going ahead, both fiscally and environmentally. Second, farm mechanisation, the viable alternative way to boost farm output through higher productivity, may be difficult to implement because of shrinking size of farm holdings – from 2.28 hectare in 1970-71 to 0.7 hectare in 2021-22. Third, India's population is expected to rise further to about 1.6 billion in 2047, and by then per capita income must increase 8 folds for India to become an advanced economy, which would mean corresponding large increase in demand for food, even if the share of food in average household consumption basket moves down gradually. Competition for land from urbanisation and industry, and expected increase in the frequency and intensity of climate shocks could potentially pose supply side constraints to farm output. Raising farm productivity, therefore, may have to be the key strategic focus, that must embrace all farmers irrespective of farm size.

A revisit of the farm-size productivity debate, using data from SAS 2018-19 and NAFIS 2021-22 corroborates the relatively higher productivity of small farms. Low marginal farm size (0.01 to 0.40 ha) category has not only witnessed improved productivity over time but also remained relatively more productive than other categories (excluding large land holdings of more than 10 ha). While the average output for households increases progressively with farm size (showing a positive relationship between farm size and farm output), average per hectare output decreases progressively with farm size (corroborating the inverse relationship). The assessment based on per hectare output is also validated by per hectare net income from cultivation (which is output adjusted for paid out cultivation related expenses). What is particularly striking, however, is that for farm holding sizes of "less than 0.01 ha" and "0.01 to 0.04 ha", the share of monthly income coming from cultivation is only 2% and 16%, respectively, as against 52% and 61% for farm sizes of "1.01 to 2.0 ha" and

"above 2h.", respectively. This clearly highlights the feeble dependence on farm income for livelihood by marginal farmers, and the critical significance of raising productivity in marginal farms to elevate average farm income levels.

A multi-pronged approach to raise productivity of marginal farms must have three major components. First, access for marginal farmers to available policy enablers must be enhanced. Both SAS and NAFIS data show that marginal farms, particularly those with less than 0.4 ha of land have relatively less access to kisan credit cards (KCC) for availing agricultural credit with interest rate subventions, crop insurance, soil health cards, and collectivisation schemes meant to empower them, such as self-help groups (SHGs), farmer producer organisations (FPOs), custom hiring centres (CHCs) and joint liability groups (JLGs). Empowering marginal farmers with fuller access to these policy enablers could improve their income from cultivation, as evident from the empirical cross-sectional regression analysis. Second, farm mechanisation needs to be promoted, either by developing farm appliances and cropping techniques suitable for adoption in small farms or through collectivisation, where farm machines could be jointly owned and used as per needs. Modern cropping practices must also adjust suitably, remaining sensitive to rising importance being assigned by India's trading partners to green prescriptions like maximum residue limits (MRLs) and no recourse to deforestation for cultivation, *etc*, that could dampen India's agri export prospects. Maximizing output while minimising input use would require a total factor productivity (TFP) focused approach, under which delivery of modern practices would require realignment of the agents of change, namely Krishi Vigyan Kendras (KVKs), agricultural universities/colleges, agri clinics and business centres, self-help groups (SHGs), farmer producer organisations (FPOs), custom hiring centres (CHCs), joint liability groups (JLGs) and rural multipurpose cooperative credit institutions at the grassroots level, to bridge information gaps and improve access to TFP enhancing cropping practices for all. In this context, the success of the recent initiative of Viksit Krishi Sankalp Abhiyan 2025, and the sub-mission on farm mechanisation (SMAM) and national mission on agricultural extension and technology (NMAET) would be crucial for raising productivity and income of small and marginal farmers. Third, while mass adoption of agtech can be a solution to raise productivity in small farms, practical hurdles to tech adoption would require a renewed policy thrust on land consolidation also, as small farm size can potentially be a constraint to farm productivity in the future, notwithstanding the past evidence of relatively higher productivity of small

farms when agriculture was largely labour-intensive and also input intensive, backed by subsidies, which may not be fiscally and environmentally sustainable in the future. Threshold regression analysis based on cross-sectional NAFIS 2021-22 data suggests that 1.65 hectare is the ideal farm size, and consolidation of smaller sized holdings can raise income of the farmers from cultivation. To power a productivity-led augmentation of rural prosperity, thus, land consolidation may be pursued as a needed structural reform, with the aim to mobilise voluntary participation by marginal farmers, to pool their land to a larger average size, through FPOs/SHGs or cooperatives. Simultaneously, it may be ensured that the ongoing initiatives for promoting adoption of agtech cover all consolidated land.

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Annex Table 1a: SAS 2018-19 - Average Monthly Income (in Rs.) from Different Sources Per Agricultural Household for Each Size Class of Land Possessed

Size class of land possessed (hectares)	Income from wages (Rs.)	Income from leasing out of land (Rs.)	Net receipt from crop production (Rs.)	Net receipt from farming of animals (Rs.)	Net receipt from non-farm business (Rs.)	Total income (Rs.)
<0.01	6,015	541	**174**	956	407	8,093
0.01 - 0.40	4,619	250	**925**	1,132	793	7,719
0.41 - 1.00	4,061	78	**2,535**	1,361	531	8,567
1.01 - 2.00	3,781	68	**5,140**	1,914	513	11,416
2.01 - 4.00	3,528	128	**9,257**	2,626	655	16,194
4.01 - 10.00	4,478	471	**18,595**	3,200	640	27,384
10.00+	3,766	595	**55,666**	7,467	2,148	69,642
all sizes	**4,190**	**157**	**3,584**	**1,552**	**638**	**10,119**

Annex Table 1b: SAS 2012-13 - Average Monthly Income (in Rs.) from Different Sources Per Agricultural Household for Each Size Class of Land Possessed

Size class of land possessed (ha)	Income from wages/ salary (Rs.)	Net receipt from cultivation (Rs.)	Net receipt from farming of animals (Rs.)	Net receipt from non-farm business (Rs.)	Total income (Rs.)
< 0.01	2902	**30**	1181	447	4561
0.01 - 0.40	2386	**687**	621	459	4152
0.41 - 1.00	2011	**2145**	629	462	5247
1.01 - 2.00	1728	**4209**	818	593	7348
2.01 - 4.00	1657	**7359**	1161	554	10730
4.01 -10.00	2031	**15243**	1501	861	19637
10.00 +	1311	**35685**	2622	1770	41388
all sizes	**2071**	**3081**	**763**	**512**	**6426**

Annex Table 2a: NAFIS 2021-22 - Average Monthly Income by Size Class of Land Possessed (In Rupees per month per household)

Size Classes/ Sources of Income	<0.01 ha	0.01-0.40 ha	0.41-1.00 ha	1.01-2.00 ha	>2.00 ha	All Agri Households
Cultivation	**225**	**1,792**	**4,193**	**8,684**	**12,930**	**4,476**
Livestock Rearing	2,752	1.449	1,507	1,897	2,196	1,677
Other Enterprises	1,393	1,681	2,083	2,527	2,687	2,010
Wage Labour	3,183	2,999	2,052	1,033	1,095	2,238
Govt / Pvt Service	3,420	3,309	3,568	2,324	2,136	3,150

Other Sources	136	117	104	84	133	110
Total Income	**11,110**	**11,347**	**13,509**	**16,548**	**21,177**	**13,661**

Annex Table 2b: NAFIS 2016-17 - Average Monthly Income by Size Class of Land Possessed (In Rupees per month per household)

Size Classes/ Sources of Income	**<0.01 ha**	**0.01-0.40 ha**	**0.41-1.00 ha**	**1.01-2.00 ha**	**>2.00 ha**	**All Agri Households**
Cultivation	**566**	**1488**	**2501**	**4485**	**7572**	**3140**
Livestock Rearing	1345	517	624	763	978	711
Other Enterprises	251	384	455	416	1030	489
Wage Labour	3508	2932	3044	2777	3340	3025
Govt/ Pvt Service	2192	1281	1398	1419	1612	1444
Other Sources	274	48	148	130	150	122
Total Income	**8136**	**6650**	**8171**	**9990**	**14682**	**8931**