Population Ageing Structure in India: It's Implications for Agriculture Developments and Farmers Empowerment – Review

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Abstract

Background: India's rapidly aging population presents challenges, particularly in rural areas where agriculture is the primary livelihood. The elderly farming population faces diminishing physical capacity and productivity, highlighting the need to understand how aging affects agricultural labor and household economics. Methods: This study examines the participation of elderly farmers in agriculture using semi-structured questionnaires, motion tracking devices, and regression analysis. Data were collected on demographic factors, physical demands of agricultural tasks, and involvement in farming activities across various rural regions. Multiple linear regression was applied to analyze the relationship between aging, agricultural productivity, household income, and socio-economic variables. Results: Preliminary findings reveal that farmers aged over 70 experience reduced physical capacity for high-intensity agricultural tasks. Households with larger landholdings are more financially stable, while landless households face greater economic vulnerability. Gender disparities were noted, with female farmers showing more significant limitations in physical work. The presence of elderly members increases household expenses by 12%, while contributing 14.3% more to household income. Additionally, each year of increased age in elderly members correlates with a 0.2% rise in expenses. Conclusion: The aging agricultural workforce in India underscores the need for policies tailored to elderly farmers. These policies should promote less physically demanding roles, ensure economic security, and strengthen social welfare systems, contributing to a more inclusive and sustainable rural economy.

Keywords: Aging population, Agricultural labor, Rural economy, Household dynamics, Elderly farmers

Significance | This study demonstrated the economic and labour challenges posed by aging farmers, emphasizing the need for targeted rural policies.

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Introduction

India is undergoing a demographic transformation characterized by accelerated population aging, presenting significant socio-economic and structural challenges. The growth rate of the elderly population individuals aged 60 and above is three times higher than the overall population growth rate (Sathyanarayana et al., 2014). This demographic shift is driven by declining fertility rates, increased longevity, and the aging of large cohorts (Lee et al., 2014). Currently, approximately 109 million Indians are over the age of 60, with projections indicating an increase to 300 million by 2050 (United Nations, 2015; Kardile & Peisah, 2017). Such rapid growth raises concerns about the quality of life for the elderly, especially in rural areas where traditional family support systems are weakening, and government-provided welfare remains inadequate (Verma et al., 2017; Ghosh et al., 2017).

The economic implications of aging in India are profound. Less

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than 10% of elderly individuals receive any form of pension, and only 14% can rely on financial support from family or friends (Uppal & Sarma, 2007; Alam et al., 2014). With the shift from joint family systems to nuclear families, vulnerabilities among older adults have increased, exacerbating their dependence on India's underdeveloped social and healthcare infrastructure (Agrawal, 2012). This underscores the need to explore income sources, savings, and work participation as critical components of elderly well-being.

Agriculture has long been the backbone of India's rural economy, employing over 50% of the workforce and serving as a primary source of livelihood for 70% of the rural population (The World Bank, 2010; Alam et al., 2014). Despite its declining contribution to GDP now around 17% due to industrial and service sector growth (KPMG, 2016) agriculture remains vital for rural sustainability. For aging farmers, agriculture provides continued employment opportunities, although these are often constrained by declining physical capacity and productivity (Khanal & Mishra, 2017).

Understanding the implications of population aging on agricultural productivity is essential. As farmers age, their capacity to engage in day-to-day agricultural activities diminishes. This necessitates estimating savings for food-secure old age and identifying alternative employment opportunities for the elderly. Roles such as childcare, food preparation, and educational support could serve as supplementary employment options, fostering economic stability and social inclusion for older individuals.

The rapid industrialization of India, coupled with urban migration among younger generations, has led to a shrinking agricultural workforce (Sharma, 2016). While employment in secondary and tertiary sectors offers higher wages, these opportunities are threatened by automation and reshoring trends in developed countries, which reduce labor-cost advantages (UNCTAD, 2016). Simultaneously, global food demand is projected to rise by 59–98% between 2005 and 2050, driven by population growth, increased incomes, and dietary shifts toward higher protein consumption (Valin et al., 2013; FAO, 2012a).

Expanding agricultural land to meet food demand is not a viable solution for India due to ecological and social trade-offs. The per capita availability of agricultural land has already declined from 3,800 m^2 in the 1960s to below 1,500 m^2 today (FAO, 2015). Investments in land productivity through irrigation, crop diversification, and precision farming technologies are urgently needed. The Indian government has sought to address these challenges by promoting public and private investment in agriculture, including foreign direct investment in critical areas such as fertilizers, agricultural machinery, and seed development (IBEF, 2013b).

The aging farming population faces additional challenges due to the heavy reliance of modern agriculture on fossil fuels. Oil and gas are critical for producing fertilizers, pesticides, and energy, yet their costs and potential shortages threaten agricultural sustainability (Green, 1978). Furthermore, the agricultural sector significantly contributes to greenhouse gas emissions, intensifying climate change impacts (Colin, 1997). These dynamics disproportionately affect the poorest and oldest households, making them especially vulnerable to rising food prices and production constraints.

This study examines the participation of older farmers in agricultural activities, the physical demands of these tasks, and their distribution across age and gender. Utilizing semi-structured questionnaires, motion tracking devices, and regression analysis, the research provides insights into the aging population's changing role in agriculture. The findings contribute to discussions on extending working life, promoting health, and redefining rural life structures to align with longer life expectancy. Longevity is reframed not as prolonged old age but as an opportunity to live longer and healthier lives, adaptively engaging across all life stages.

Population Ageing in Rural India

Declining Birth and Death Rates

Population ageing refers to the increasing median age of a population due to declining fertility rates and rising life expectancy (UNDP, 2005). Among these, declining fertility has been the primary driver (Rosenzweig, 1997). This demographic shift manifests as a decrease in the proportion of children within the population and a simultaneous increase in the elderly population. Figure 1 illustrates this trend using India's crude birth and death rates.

Globally, the population aged 60 years and above has tripled since 1950, with projections estimating it will reach 2.1 billion by 2050 (UN, 2015) (table 2). However, the pace and extent of ageing vary significantly across countries. Developing nations, experiencing rapid fertility transitions, are ageing faster than developed countries, giving them less time to adapt to the associated challenges (UN, 2001). In response, many countries are adopting the "active ageing" model, which emphasizes the contributions of older adults to society. This model promotes their engagement in activities such as employment, volunteering, community service, and childcare, positively influencing their physical and mental well-being.

In India, the decline in fertility rates and rising life expectancy are relatively recent phenomena. Until the early 1950s, high birth rates followed by high death rates maintained a small elderly population. This pattern changed in the 1960s when death rates fell sharply, and life expectancy at age 60 rose significantly, from 41.2 years in 1960 to 68.3 years in 2015. Fertility rates began to decline during the 1970s, reaching 2.2 children per woman by 2017, with most Indian states falling below the replacement level of 2.1 (Chandra, 2016; Government of India, 2015b). As a result, the elderly population has grown faster than the general population a trend expected to persist (Figure 2).

The United Nations Population Division forecasts that by 2050, 34% of India's population will be aged 50 and above, and by 2042, the share of those aged 60 and older will surpass that of children aged 14 and younger (UNPD, 2011; Chatterji, 2008). Bloom (2011) argues that the reduction in youth dependency due to declining fertility rates will partially offset the burden of old-age dependency (table 12). Nonetheless, the shrinking pool of working-age adults to support the growing elderly population remains a significant challenge. Census data from 1961 revealed that approximately 11 older adults were dependent on every 100 working-age individuals. By 2011, this figure had risen to 14 and is projected to increase to 31 per 100 by mid-century (Table 2).

Gender and Regional Variations

The sex ratio among older adults has shifted in favor of females over the past two census cycles. However, such broad trends often conceal significant regional disparities. For instance, fertility rates in southern states are nearly half those in northern states, resulting in varied ratios of working-age to non-working-age populations across regions. These differences will amplify the uneven effects of an ageing population across the country.

Population pyramids provide a striking visual representation of this demographic shift. Figures 3 and 4 show how India's population structure has transformed from a youthful, pyramid-shaped distribution to an ageing, coffin-shaped one, highlighting the magnitude of this transition.

The Social Cost of Population Aging

Population aging imposes significant social and economic costs as societies face increasing expenditures on health care and social security (table 1). Governments are often forced to navigate the difficult trade-offs between raising taxes to fund these expenses or scaling back the provision of vital services. Social security systems, particularly in countries reliant on pay-as-you-go (PAYG) models, are becoming increasingly strained. This is primarily due to the growing disparity between the lengthening of retirement periods and the relatively stagnant extension of active working lives. For instance, global life expectancy at birth rose from approximately 52.5 years in 1960 to 71.7 years in 2015 a remarkable increase of over 19 years in just five decades (The World Bank, 2018b). However, during the same period, retirement ages have barely shifted. In the United States, the official retirement age rose modestly from 65 in 1960 to 66 in 2017 (Carroll, 2010), while in India, it increased from 58 to 60 years over a similar timeframe (Hindustan Times, 2006).

This demographic trend impacts pension systems in two primary ways: (1) a larger proportion of the population becomes eligible for benefits, and (2) beneficiaries draw these benefits for extended periods (Scardino, 2009). Ensuring adequate income for the growing elderly population without placing undue financial pressure on younger generations presents one of the greatest challenges of our time. To address this, pension systems will require comprehensive reform, including policies to encourage prolonged workforce participation among older individuals. Countries with PAYG systems are especially vulnerable, as these systems rely on a stable ratio of active contributors to beneficiaries. The demographic shift, however, reveals an increasing number of retirees compared to active workers, threatening the financial sustainability of these schemes.

In India's formal sector, retirement ages typically range between 55 and 65 years (Rajan, 2010). However, a significant portion of the Indian workforce operates within the informal sector, which has no standardized retirement age. The predominantly agricultural nature of the Indian economy accommodates older workers, as agriculture often does not demand the specialized skills required in the manufacturing or service sectors. This enables many older adults to remain economically active. During the 1980s, 1990s, and early 2000s, over 90% of Indian workers were employed in the informal sector, where they received no retirement benefits, leaving them financially dependent in old age (table 11), (Rajan, 2010). This phenomenon mirrors broader trends across the developing world (Chen, Jones, and Domingo, 1989; Choe, 1989; Nasir and Ali, 2000; Perera, 1989).

Looking ahead, Mullan predicts that by 2050, industrialized nations will stabilize their demographic balance, with elderly populations comprising around 30% of the total population. Developing countries, however, are expected to experience a delayed but faster demographic transition. For these nations, the current youthful demographic profile represents a unique opportunity for accelerated economic growth a phenomenon often referred to as the "demographic dividend." Realizing this potential requires reducing birth rates to lower the dependency ratio, thereby enabling the working-age population to support a smaller cohort of dependents. Strategic investments in health, education, and economic opportunities for youth are critical to harnessing this demographic advantage.

In contrast, many least-developed countries face significant hurdles in managing their demographic transitions. High fertility rates persist due to limited access to family planning and reproductive health services (Gribble and Bremner, 2012). Consequently, children and adolescents constitute a disproportionately large share of the population. However, with adequate investments in their well-being and education, these young populations could drive substantial economic progress.

To ensure the sustainability of social security systems, proactive measures such as job creation and policies to delay retirement are essential. For example, promoting higher labor market participation among older individuals could partially offset the labor supply declines caused by aging populations (Clark et al., 2010). Countries with high unemployment rates, low retirement ages, low female workforce participation, and limited immigration may require tailored strategies to maximize labor force potential. Mullan underscores that high labor market participation is as critical as economic growth, though its effects will vary across nations based on their unique demographic and economic contexts.

Major studies on population aging and workforce participation

Population aging and workforce participation have been central themes in understanding socio-economic dynamics in India, with two pivotal studies forming the backbone of available data: the Census of India 2011 (Government of India, 2015b) and UNFPA's Report on the Status of Elderly in Select States of India 2011 (Alam et al., 2014). Both studies were conducted concurrently, offering complementary insights into the phenomenon. While the Census of India provides a comprehensive nationwide overview of aging and workforce participation, encompassing the entire population, the UNFPA report focuses on a targeted sample of approximately 10,000 elderly respondents across select states, enabling a nuanced understanding of specific regional and demographic patterns.

The Census of India reveals critical statistics: 42% of adults aged 60 and older and 22% of those aged 80 and older are still active in the workforce. This dataset extends its analysis by urban and rural division, state-specific participation, gender distinctions, and varying durations of work activity. Furthermore, it categorizes workforce participation into roles such as cultivators, agricultural laborers, household industry workers, and others, offering a broad classification of economic activities. However, its reliance on high-level data presents significant limitations. For instance, it does not specify the exact agricultural activities performed, the physical or cognitive effort required, or the nature of everyday involvement in agricultural tasks. Additionally, the data are largely self-reported, which may introduce biases, and the analysis does not consider critical variables like land ownership or household size. Age is often reported in ranges rather than as individual data points, restricting detailed age-specific insights.

While this high-level data is useful for overarching policy formulation, it falls short in addressing the nuanced implications of aging on agricultural productivity and workforce dynamics. These gaps, such as the need for more granular data on labor intensity, agricultural practices, and household contexts, highlight the necessity for further in-depth research. Bridging these gaps can provide a clearer picture of how aging influences workforce participation, particularly in agriculture, and inform more targeted, effective interventions to support the aging population in India.

Statistical data analysis

Statistical data analysis will be conducted on samples collected using semi-structured questionnaires and accelerator-based devices. The data will be structured, normalized, and formatted in Microsoft Office, after which it will be analyzed using simple and stepwise multiple linear regression techniques in SPSS 23. This analysis will address several key questions, such as how aging affects landless versus land-rich rural households in terms of income and expenses, whether household size and structure (including the number of dependents) impact household income and expenses, and how agricultural involvement influences household financials. Regression analysis is a critical tool for drawing inferences from the data and understanding patterns within the population. A detailed list of all variables used in the analysis, along with the number of samples for each regression, is provided in Table 8.

Simple linear regression is a statistical method used to examine the relationship between two variables (table 6), while stepwise multiple regression is a more complex, semi-automated process. The latter involves successively adding or removing variables based on the t-statistics of the estimated coefficients. The goal is to minimize the number of variables in the model, as unnecessary regressors can decrease the precision of the coefficient estimates and the accuracy of predictions (NCSS, 2015). There are two approaches to stepwise regression: the forward method, which begins with no variables and adds them one by one, and the backward method, which starts with all predictor variables and removes those that do not significantly predict the dependent variable (Hill & Lewicki, 2006).

The statistical analysis will be structured as follows. Descriptive statistics, including measures such as the average, minimum, maximum, and standard deviation, will first be presented for the data gathered through the main questionnaire. This will be followed by an analysis of the elderly data and movement tracking device results. The regression output for the main questionnaire data will then be provided, including results for elderly farmers. Agricultural intensity data, reflecting the activities performed by farmers, will also undergo regression analysis, with comparisons made between different age groups. Only statistically significant regression results will be reported. Furthermore, during each simple linear regression (table 3), key assumptions such as linearity between dependent and independent variables, statistical independence of errors (table 5), homoscedasticity, normality of error distribution, data distribution, and multicollinearity in the case of multiple linear regression will be tested (table 7). Table 9 will outline all the regressions performed, specifying dependent and independent variables and indicating the hypotheses being tested. Regressions marked with an asterisk will not test predefined hypotheses.

Results and Discussion

Descriptive Statistics

Table 10 presents the descriptive statistics for the dataset, including measures such as the mean, minimum, maximum, and standard deviation for various variables. These statistics are derived from the primary section of the questionnaire, supplemented by data from the elderly section (table 4). Additional measures are included where relevant to provide a more precise representation of the variables. For instance, while the average number of elderly household members across all surveyed households is 0.7, the average for households that actually include elderly members is 1.3. This distinction highlights the variation in household composition, specifically the presence of elderly individuals.

The data reveals considerable variability across sub-districts and villages, as indicated by the standard deviation for each variable. This variation suggests that demographic factors, such as age and household composition, differ significantly across the surveyed population. For example, while the average age of the farmers in the district is 44.7 years, the age range spans from 18 to 98 years, demonstrating a broad spectrum of age groups within the sample. Similarly, household size, number of children, elderly, and dependent members all exhibit relatively high standard deviations, indicating diverse household structures. The only exception to this trend is the average age of elderly family members, which is 68.2 years, with a comparatively smaller standard deviation of 7.9. This suggests a more consistent age range within the elderly group.

Despite these variations in household and demographic characteristics, certain trends in agricultural involvement and labor intensity are clear. The average number of hours worked per day by farmers is one of the most significant descriptive statistics. It provides insight into the length, intensity, and physical demands of agricultural labor. On average, farmers worked 5.6 hours per day during the least busy month (May), with a marked increase to 10.4 hours per day during the busiest month (November). The intensity of the labor, rated with an average score of 3.7 (indicating "overall difficult"), further emphasizes the physically demanding nature of the work. The majority of farmers described the intensity of individual agricultural tasks as "difficult" or "moderate." These statistics are crucial not only for understanding the workload of farmers but also for subsequent regression analyses and comparative studies.

The agricultural involvement index, which synthesizes both the hours worked and intensity of labor over the past year, further quantifies the effort exerted by farmers. It is notable that the standard deviations for all three measures hours worked, agricultural intensity, and agricultural involvement were relatively low, except for hours worked during the least busy month. This anomaly is primarily due to a substantial number of farmers reporting no work during that period, thus distorting the average for the least busy month (figure 5).

When comparing the agricultural involvement and intensity indices for heads of households and elderly farmers, significant differences emerge. The indices for elderly farmers are approximately half those of their younger counterparts, with elderly farmers working, on average, one-third fewer hours. This gap is largely due to a higher proportion of elderly individuals who are unable to work, as reflected in the greater standard deviation for the elderly group. However, when considering only those elderly farmers who reported working (around 90% of the sample), the average hours worked increases from 6.7 to 8.3 hours per day, reducing the discrepancy between the two groups. This trend, showing that elderly farmers who continue to work contribute almost as much to agricultural involvement as their younger counterparts, with slightly higher intensity levels in some cases.

This disparity between the elderly and younger farmers is partially attributed to the inclusion of elderly heads of household in the survey. Approximately 11.6% of respondents were aged 60 or older, which skews the results for elderly farmers. Furthermore, the methodology for calculating hours worked for heads of households involves averaging data across three months, including the least busy, busiest, and the preceding months. In contrast, the methodology for elderly farmers considers only the preceding month, which is typically the busiest period. Consequently, the data for heads of households is influenced by farmers who worked during the busiest months but not during the least busy month (8.5% of the sample), which results in lower average values. Therefore, the slightly inflated averages for elderly respondents and slightly understated averages for heads of households create a misleading sense of parity between the two groups.

To further explore the relationship between age and labor intensity, the data were plotted for hours worked, agricultural intensity, and agricultural involvement against the farmer's age . This visualization helps clarify how these variables correlate across different age groups.

Given the challenges of comparability due to methodological differences and the relatively small sample size, the data for heads of households and elderly farmers were combined for analysis. This combination was limited to male farmers, as the sample of female heads of households and elderly farmers was too small for reliable analysis. Additionally, data were grouped into age brackets to smooth out variability caused by small sample sizes (e.g., only five farmers aged 47 and one aged 44), resulting in more stable and interpretable trends.

However, interpreting these results requires caution. For instance, the agricultural intensity index shows an increase in labor intensity that peaks in the 65-69 age group. This pattern contradicts expectations, suggesting that older farmers may engage in more physically demanding tasks than their younger counterparts. Such a finding invites further investigation into the factors that influence labor intensity and the types of agricultural tasks that older farmers are likely to undertake.

To better understand the phenomenon of younger farmers being expected to work more intensely than their older counterparts, we must first examine how the research question is framed. The study involved a questionnaire where respondents were asked to identify the three most important agricultural activities they performed during a given month and then rate the physical demand of each activity. This type of question naturally presents a challenge because older farmers may perceive the same activities as more physically demanding due to the natural effects of aging, such as reduced stamina, strength, or mobility. This could lead older farmers to rate the intensity of work as higher compared to younger farmers, potentially skewing the data in favor of older farmers' subjective experiences.

The source data for the regression analysis included only those activities that were reported by at least 10 farmers, resulting in four activities being selected for the analysis. These activities were: binding rice straws, harvesting rice, plowing potatoes, and threshing rice. Data for female farmers did not meet the inclusion criteria, as only 24% of the samples were female (76% of the measurements involved male farmers). Thus, the regression model only considered data from male farmers. Interestingly, binding rice straws was the only variable found to be statistically significant in the regression model.

The regression model itself exhibited low predictive power, meaning that while the data may have supported the hypothesis (H0l) that work intensity declines with each additional year of age, the model was not able to explain the observed variation in the intensity of work effectively. The results do, however, lend support to the idea that older farmers experience a decline in work intensity over time, which helps clarify the seemingly paradoxical results of the alternate hypothesis (H0b), which posited that the intensity of work increases with age. The finding that older farmers report lower intensity levels suggests that, over time, their physical capacity may limit the amount of labor they can perform, despite their years of experience.

Provides a deeper dive into the relationship between age and the perceived intensity of agricultural activities. The figure shows the correlation between the reported and measured intensity of various activities for different age groups. It reveals that six age-activity combinations had a correlation of 90% or higher, while four other combinations had correlations ranging from 80-89%. Notably, the 40-79 age groups predominated in seven of these combinations, indicating that older farmers were more consistent in both reporting and exhibiting a similar level of intensity in their activities. This trend was expected, as older farmers in the 40-79 age range displayed a slightly lower standard deviation in their reported intensity levels compared to the younger 10-39 age group. However, the fact that 75% of the combinations had correlations below 90% suggests that the high correlation in some cases could be due to chance rather than a robust relationship between reported and measured intensity. Additionally, the low explanatory power of the regression model further weakens the argument that the measured intensity (based on objective data like movement or heart rate) fully aligns with the perceived intensity reported by the farmers.

It's important to note that these findings should not diminish the credibility of the fitness tracker data. The discrepancies between perceived and measured intensity may be explained by the fact that subjective perceptions of intensity are influenced by a variety of factors beyond just the physical activity itself. For example, farmers may feel that a task is more demanding due to the mental or emotional strain involved, even if the actual physical exertion (as measured by steps, movement, calories burned, or heart rate) is lower than expected. In essence, while the fitness tracker measurements offer an objective view of physical activity, the farmers' subjective experiences of intensity may differ due to personal and contextual factors that are not captured by the tracker data alone.

Estimating the Cost of Aging

The third research objective focuses on estimating the financial impact of aging on individual households, particularly after a farmer's active involvement in agriculture diminishes or reaches a certain threshold. To address this, two hypotheses are considered: (1) H0j, which examines whether the age of elderly household members influences household costs, and (2) H0k, which investigates whether the number of elderly household members has any effect on household expenses.

Although the regression models exhibit relatively low predictive power, the results support both hypotheses. Specifically, household expenses are found to increase with both the age and number of elderly members. For each additional elderly household member, expenses rise by 12%, while every additional year in the age of elderly members corresponds to a 0.2% increase in household costs. However, it is crucial to also consider the impact of aging on household income when assessing the overall effect on household finances.

A positive correlation between the independent variables and household income, showing a predicted 14.3% increase in income with each additional elderly household member. Notably, household income is expected to grow at a rate 2.3 percentage points faster than household expenses for every additional elderly member. This challenges the common assumption that elderly members are predominantly net drains on household budgets, suggesting a more complex and potentially beneficial role for elderly individuals within rural households.

Despite these findings, the extremely low explanatory power of both regression models warrants caution in interpreting the results. A more extensive study with a larger sample size would be necessary to draw more definitive conclusions.

Supplementary Regression Output

The primary regression models discussed earlier aim to address specific research questions based on the hypotheses set forth in the study. However, this section delves into additional regression analyses that explore the relationship between household income and expenses and several other independent variables. These variables include key demographic and socio-economic factors such as the farmer's age, land ownership, years of education, household size, number of children, number of dependent members, as well as agricultural-related factors like involvement in agriculture, agricultural intensity indices, hours worked, years of working outside agriculture, and the average age of children in the household.

Land Ownership and Household Income/Expenses

A crucial finding from the supplementary regression analyses is the relationship between land ownership and household income and expenses. Specifically, the results suggest that each additional acre of land is expected to increase household income by approximately 5.4%. This increase in income is linked to the greater productive capacity that comes with larger landholdings, as farmers can grow more crops or rear more livestock, resulting in higher revenues. However, the regression also reveals that household expenses rise with land ownership, though at a slower rate—0.6 percentage points less than the increase in income.

This slower increase in expenses despite higher income may seem counterintuitive at first, particularly in a state where nearly half of the population comprises marginal or landless farmers. For many farmers, land serves not only as a direct source of income but also as a crucial safety net and coping mechanism in times of financial strain. One plausible explanation for this observation is that larger landholdings require more investment in agricultural inputs, such as seeds, fertilizers, and irrigation systems, as well as hiring labor to maintain or expand agricultural production. Additionally, larger landholdings may necessitate capital expenditures for agricultural equipment or durable household goods, which could also drive-up household costs. While the small sample size limits the ability to control for other variables, the findings suggest that owning more land is accompanied by significant financial commitments.

Years of Formal Education

In a similar vein to land ownership, the number of years of formal education the farmer has completed also correlates positively with both household income and expenses. For each additional year of education, household income is expected to increase by 2.4%, while household expenses are predicted to rise by 2%. This finding aligns with the general expectation that higher education opens up better economic opportunities, leading to higher income levels. In practical terms, an additional year of education contributes to household income in a way comparable to owning an additional half acre of land.

However, this comparison is symbolic, as formal education, particularly college education, generally leads to significantly higher earnings, while the study sample's average of 7.6 years of education may not capture enough cases with higher education levels. This limitation in the data could potentially skew the predictions for household income toward the lower end of the educational spectrum, as the majority of farmers in the sample may not have higher education degrees.

Household Size and its Impact on Income and Expenses

Further regression analyses consider household size as an independent variable. According to the data, an average surveyed household consists of 8.5 members, with 4.8 of these being adults. As expected, larger households are predicted to experience higher income and expenses. This is primarily due to the increased number of working-age adults, who contribute to both household income through employment and productivity. Similarly, larger households with more elderly members may benefit from the support provided by older, potentially retired individuals, as outlined in the hypotheses H0j and H0k. This support can contribute to household finances, thus influencing overall budget dynamics.

As in previous models, household income is expected to increase at a faster rate than household expenses as the number of household members rises, reflecting the productive contributions of adults and the net positive role that elderly members may play in managing household resources.

Dependent Household Members

When considering the number of dependent household members as an independent variable, the regression output reveals similar patterns, but with notable differences. Specifically, the expected increase in household income is somewhat lower than the expected increase in household expenses, which contrasts with the findings for household size. The explanation for this discrepancy lies in the composition of dependent household members, which include both elderly members who tend to contribute to the household financially and children, who are typically dependent and can be a drain on household resources.

Children, as net beneficiaries of household income, require significant expenditures on food, education, and healthcare, whereas elderly household members may contribute to the household through pension benefits, social security, or other means. This mix of contributing and non-contributing dependents results in the predicted increase in household expenses outpacing the increase in income. Despite the lower predictive power of the model, this pattern is plausible and aligns with the complex financial dynamics that characterize households with dependent members.

Presents similar insights as the previous analyses, but this time focusing on the prediction that household expenses will increase at a faster rate than household income. This trend aligns with expectations, particularly when considering that children are typically net beneficiaries in a household, meaning they contribute little to the household's income and are a significant drain on the

Table 1. Indicators of aging for the Indian population for census years 1961-2011 (Bakshi and Pathak, 2016)

Census Year	Number of older adults	Percentage of older adults in the population of India	Old-age dependency ratio (per 100 adults)	Sex ratio among older adults (per1,000 older males
1961	24,712,109	5.63	10.56	929
1971	32,699,731	5.97	11.47	938
1981	43,167,329	6.49	12.04	960
1991	56,681,640	6.80	12.19	930
2001	76,622,321	7.47	13.08	1,029
2011	103,849,040	8.61	14.22	1,033

Table 2. List of dependent and independent variables used in regression analyses

Variable	classification	Unit of measure	Number of samples
Farmer's age†	Independent	Year	388
Household size	Independent	Person	388
Number of elderly household members	Independent	Person	388
Number of children within household	Independent	Person	388
Number of dependent household members	Independent	Person	388
Average age of elderly household members	Independent	Age	388
Average age of children within household	Independent	Age	388
Land ownership	Independent	Acre	388
Household income	Dependent	000 USD	388
Household expenses	Dependent	000 USD	388
Agricultural involvement index†	Dependent*	Index number	388
Agricultural intensity index†	Dependent*	Index number	388
Hours worked†	Dependent*	Hour	388
Years of education	Independent	Year	388
Age at first agricultural employment	Independent	Year	388
Years of working outside agriculture	Independent	Year	388

Note 1: Variables marked with an asterisk (*) can function as both dependent and independent variables.
Note 2: Variables marked with a dagger (†) are also used for analyzing the elderly household member section.

Table 3. List of performed regressions, variables, samples, and hypothesis identifiers

Independent variable	Dependent variable	Tested
Farmer's age	Agricultural involvement index	*H0a*
Farmer's age	Agricultural intensity index	*H0b*
Farmer's age	Hours worked	*H0c*
Farmer's age	Household income	*
Farmer's age	Household expenses	*
Household size	Agricultural involvement index	*H0g*
Household size	Agricultural intensity index	*H0h*
Household size	Hours worked	*H0i*
Household size	Household income	*
Household size	Household expenses	*
Number of elderly household members	Household income	*
Number of elderly household members	Household expenses	*H0k*
Number of children within household	Household income	*
Number of children within household	Household expenses	*
Number of dependent household members	Household income	*
Number of dependent household members	Household expenses	*
Average age of elderly household members	Household income	*
Average age of elderly household members	Household expenses	*H0j*
Average age of children	Household income	*
Average age of children	Household expenses	*
Land ownership	Agricultural involvement index	*H0d*
Land ownership	Agricultural intensity index	*H0e*
Land ownership	Hours worked	*H0f*
Land ownership	Household income	*
Land ownership	Household expenses	*
Agricultural involvement index	Household income	*
Agricultural involvement index	Household expenses	*
Agricultural intensity index	Household income	*
Agricultural intensity index	Household expenses	*
Hours worked	Household income	*
Hours worked	Household expenses	*
Years of education	Household income	*
Years of education	Household expenses	*
Years of working outside agriculture	Household income	*
Years of working outside agriculture	Household expenses	*

Table 4. Descriptive statistics for select variables (main questionnaire and elderly section)

Variable	Average	Alt. Average	Max	Min	SD
Farmer's age	44.7	-	98.0	18.0	11.4
Household size	8.5	-	40.0	1.0	5.1
Number of elderly household members	0.7	1.3	5.0	-	0.8
Number of children within household	3.0	3.4	20.0	-	2.4
Number of dependent household members	3.7	3.9	23.0	-	2.6
Average age of elderly household members	68.2	-	100.0	60.0	7.9
Average age of children	8.9	-	17.0	1.0	4.5
Land ownership	2.1	2.5	75.0	-	4.6
Household income	1.1	-	37.8	-	2.2
Household expense	1.3	-	39.5	0.2	2.3
Household savings	-0.2	-	1.2	-3.5	0.4
Agricultural involvement index	30.5	-	57.1	10.3	7.8
Agricultural intensity index	3.7	-	4.8	2.4	0.5
Hours worked (all months)	8.3	-	15.0	2.3	1.9
Hours worked (busiest month)	10.4	10.4	17.0	4.0	2.1
Hours worked (least busy month)	5.6	6.2	16.0	-	3.4
Hours worked (preceding month)	8.8	8.8	18.0	1.0	2.8
Years of education	7.6	11.1	24.0	-	6.3
Age at first agricultural employment	19.2	-	51.0	7.0	6.4
Years of working outside agriculture	2.9	8.8	30.0	-	6.2
Farmer's age	67.2	-	100.0	60.0	6.8
Agricultural involvement index	14.1	30.3	70.0	-	17.8
Agricultural intensity index	1.9	4.0	5.0	-	2.0
Hours worked	6.7	8.3	15.0	-	3.6

Table 5. Simple linear regression output for farmer's age as an independent variable

Recorded intensity of agricultural Activity	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence interval	
Binding straws (rice)	55	-.29	.07	4.98		-5.110	-9.704 -.516

Note 1: Recorded agricultural intensity for male farmers only is used due to low sample size for female farmers.

Table 6. Simple linear regression output for the average age of elderly household members (†) and number of elderly household members (*) as independent variables (log-level)

Dependent variable	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence	
Household expenses*	388	.27	.07	30.89	.120	.078	.163
Household expenses†	388	.19	.03	14.57	.002	.001	.003

Table 7. Simple linear regression output for the average age of elderly household members (†) and number of elderly household members (*) as independent variables (log-level)

Dependent variable	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence	
Household income*	388	.28	.08	33.59	.143	.095	.192
Household income†	388	.20	.04	16.65	.002	.001	.003

Table 8. Simple linear regression output for land ownership as an independent variable (log-level)

Dependent variable	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence	
Household income	388	.64	.41	263.90	.054	.048	.061
Household expenses	388	.65	.42	280.32	.048	.043	.054

Table 9. Simple linear regression output for years of educations an independent

Dependent variable	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence	
Household income	388	.39	.15	70.92	.024	.019	.030
Household expenses	388	.36	.13	58.96	.020	.015	.025

Table 10. Simple linear regression output for household size as an independent variable (log- level)

Dependent variable	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence interval	
Household income	388	.31	.10	42.18	.024	.017	.031
Household expenses	388	.33	.11	48.44	.022	.016	.029

Table 11. Simple linear regression output for number of dependent household members as an independent variable (log-level)

Dependent variable	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence interval	
Household income	388	.21	.04	17.47	.031	.016	.046
Household expenses	388	.23	.05	21.65	.030	.017	.043

Table 12. Simple linear regression output fornumber of children within householdas an independent variable (log-level)

Dependent variable	N	Person corr.	Adjusted R-squared	ANOVA F and B		95.0% confidence interval	
Household income	388	.14	.02	7.46	.023	.006	.039
Household expenses	388	.17	.03	10.93	.024	.010	.038

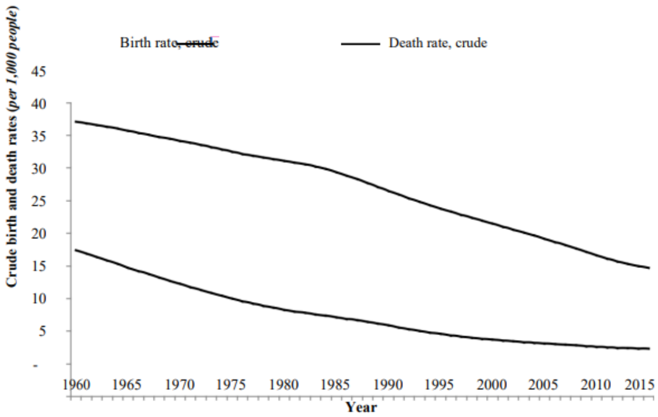

Figure 1 . Indian crude birth and death rates between 1960 and 2015 (The World Bank,2018b)

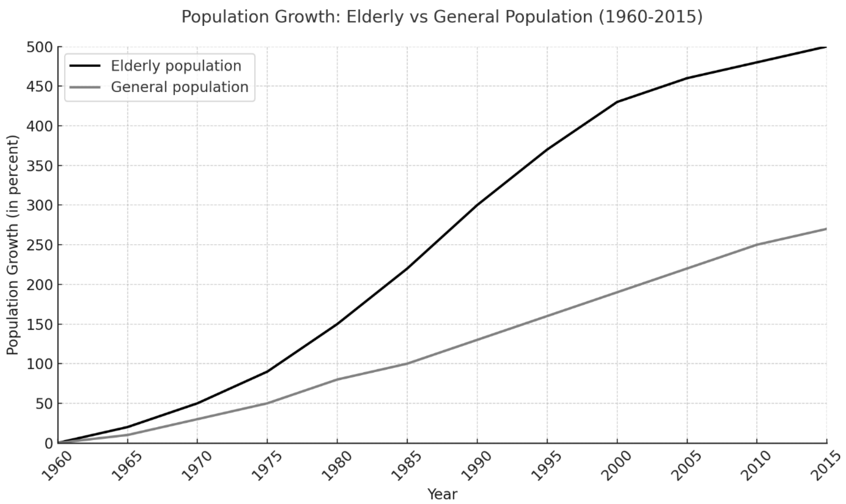

Figure 2. Indian elderly population growth compared to general population growth between1960 and 2015 (The World Bank, 2018b)

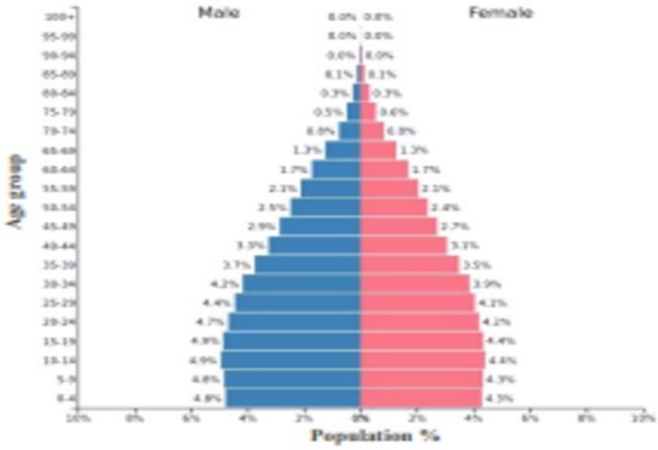

Figure 3. Estimated India population pyramid in 2018 (The World Bank, 2018b)

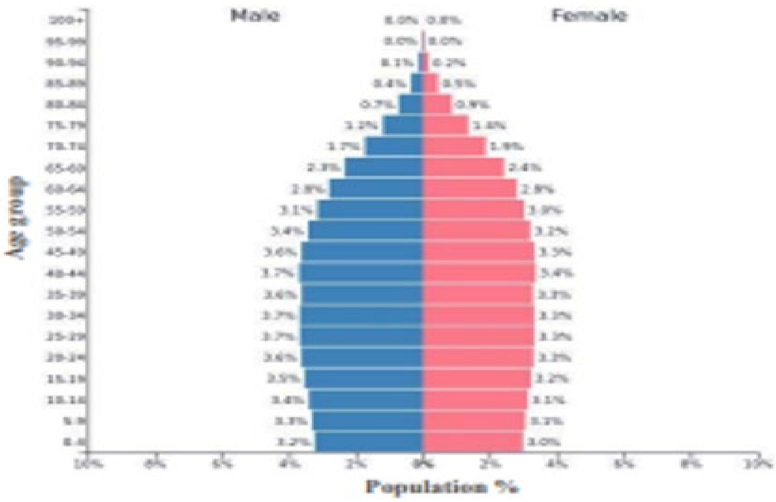

Figure 4. Estimated India population pyramid in 2050 (The World Bank, 2018b)

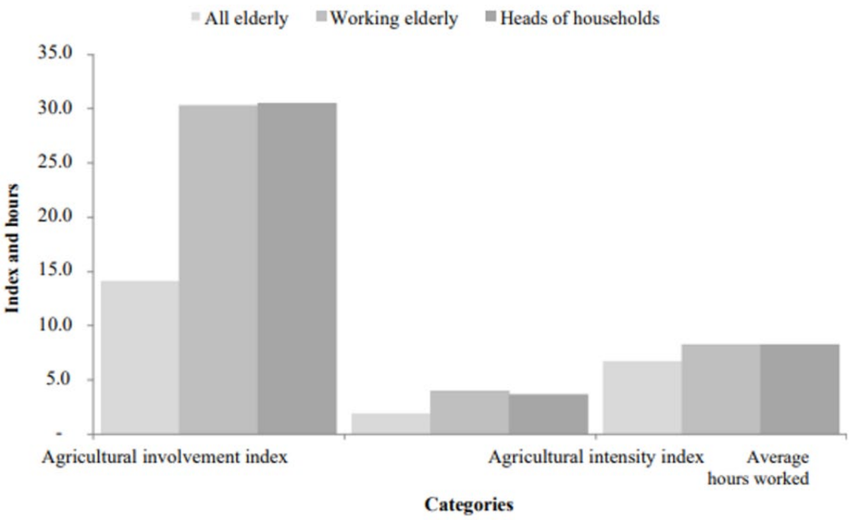

Figure 5. Comparison of hours worked, agricutural intensity and involvement for elderlyfarmers and heads of households.

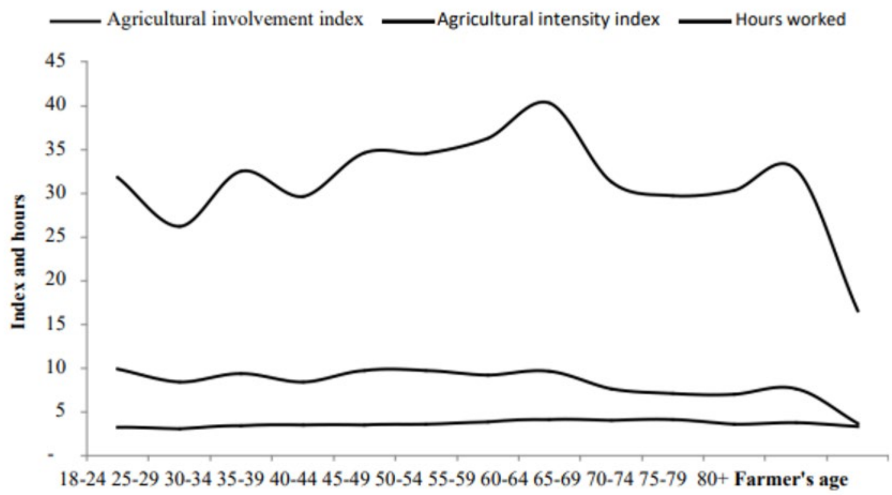

Figure 6. Comparison of hours worked, agricutural intensity and involvement by age group

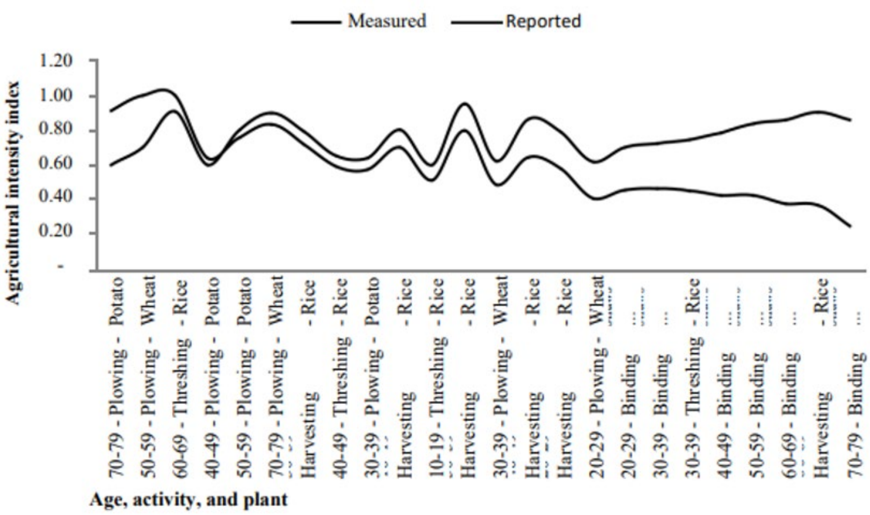

Figure 7. Measured vs. reported intensity of select agriculture activities by age group

household budget. Thus, it is reasonable to expect that the presence of children especially younger ones would lead to a disproportionate increase in household expenses compared to household income. Therefore, the patterns observed in all three models remain internally consistent, offering plausible and expected outcomes.

However, despite these expected results, some findings from the regression models are somewhat surprising and merit further discussion. Notably, the agricultural intensity and involvement indices, along with the number of hours worked, years spent working outside agriculture, and the average age of children in the household, all proved statistically insignificant in explaining variations in household income and expenses. This lack of statistical significance challenges the commonly held assumption that factors like working harder, increasing agricultural intensity, or having more work experience in non-agricultural sectors would lead to greater household income or expenses.

It is especially surprising that the number of hours worked or the intensity of agricultural involvement does not seem to influence household income or expenses. Even more unexpected is the finding that working outside of agriculture, particularly in sectors abroad, has no impact on either income or expenses. This finding contradicts the hypothesis that non-agricultural work could provide additional resources or support for households, especially when those workers are employed outside their home country. Another notable finding is that the age of children in the household also does not significantly affect income or expenses. The assumption that older children (who are closer to entering the workforce) would contribute to higher household income or lead to greater expenses due to their needs is not supported by the data. These observations could suggest the need for a larger sample size to obtain more robust results or could simply reflect that these factors are not as influential as initially assumed. Regardless, these unexpected outcomes might discourage future efforts to link work intensity, work sectors, or children's age with household financial dynamics.

Equally perplexing is the finding that a farmer's age and land ownership have no statistically significant effect on the number of hours a farmer works. Despite the descriptive statistics revealing differences in work hours between older and younger farmers, the regression models did not confirm this relationship. This contradictory result challenges the conventional belief that older farmers tend to work fewer hours due to age-related factors or shifts in farming practices, or conversely, that younger farmers work more hours to establish their households or gain more experience.

Turning to household expenses, the data reveals that the presence of elderly household members has a notable impact. Each additional elderly member increases household expenses by 12%, and every additional year in the age of elderly members increases household expenses by 0.2%. This finding aligns with the work of Bloom et al. (2010), who suggested that declining health among elderly farmers significantly raises healthcare-related expenditures, often increasing average yearly per capita healthcare costs almost fourfold. The effect of elderly household members on household income is also noteworthy, with each additional elderly member associated with a 14.3% increase in household income. This suggests that elderly individuals are net contributors to the household budget, potentially through pensions, social security, or other financial support systems, which outweigh their additional expenditure on healthcare and other needs. Thus, while elderly household members increase expenses, they simultaneously contribute to a faster increase in household income, highlighting their dual role within the household economy.

Given the prevalence of statistically insignificant regression models, it is valuable to briefly summarize some other noteworthy findings. These include the observation that a farmer's age appears to have no direct effect on household income, contrary to expectations that older farmers would earn more due to experience or accumulate greater assets over time. Additionally, the model indicates that higher land ownership is expected to increase both household income and expenses, likely due to the additional costs associated with maintaining more land, but also the potential for increased agricultural output. Furthermore, the regression analysis found that higher levels of formal education among farmers are associated with higher household income and expenses, suggesting that education might correlate with more profitable farming practices or the ability to engage in non-agricultural work that generates higher income. These insights, while interesting, still reflect the broader trend of complex interactions that may not always be captured by simple regression models.

Conclusion

The aging of India's agricultural workforce presents significant challenges to both agricultural productivity and household dynamics. Elderly farmers, particularly those over 70, experience reduced physical capacity, which affects their ability to engage in high-intensity agricultural tasks. However, those who remain active in farming contribute similarly in terms of labor intensity compared to younger farmers. The study also highlights the financial impact of aging, with elderly household members increasing both household expenses and income, suggesting a complex role in rural economies. Land ownership and education emerge as key factors influencing household income, while gender disparities in agricultural labor are evident, with women facing more limitations. The findings underscore the need for targeted policies to support elderly farmers, promote less physically demanding agricultural roles, and improve financial security through social welfare systems, ensuring a sustainable and inclusive rural economy.

Author contributions

M.A. conceptualized the project, developed the methodology, conducted formal analysis, and drafted the original writing. S.S.P. contributed to the methodology, conducted investigations, provided resources, visualized the data, and contributed to the reviewing and editing of the writing.

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Competing financial interests

The authors have no conflict of interest.

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