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RESEARCH PAPER

Is Potato Natural Farming Better off than Conventional Farming in North Eastern Hill Region of India?

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ABSTRACT

Potato being the key component of the food system of the communities residing North Eastern Hill Region (NEHR) of India, where the farming is practiced in the traditional way. The present study was conducted in the state of Meghalaya, in the three blocks, *Ri-Bhoi*, West Garo Hills and West Jaintia Hills. Primary data was collected from 56 natural farmers and 34 conventional farmers, for the year 2023-24. The growth rate in production and productivity at the world, India, and *Ri-Bhoi* District found to be positive. The study highlights potential gender-based variations in labour requirements, observing natural farming as labour intensive farming. The total cost of potato cultivation was lower in natural farming by 4 per cent. Although the yield was lower in natural farming but the net returns was significantly higher than conventional farming by mean difference of ₹ 4898.93 per hectare. There was a significant difference in the cost of human labor and FYM. Allocative efficiency suggested that the use of FYM and human labour should be increased, while the use of planting material should be reduced to achieve optimal input allocation, henceforth maximizing yield and returns.

HIGHLIGHTS

- Approximately 14 per cent more labour days was utilized under potato natural farming than conventional farming
- In both natural and conventional farming, the per cent of total female labour utilization was observed to be higher than total male labour.
- Natural farming was found to be more profitable than conventional farming
- FYM and human labour were found to be underutilized whereas, planting material was found to be overutilized in potato both farming.

Keywords: Potato, natural farming, conventional farming, allocative efficiency, cost and return

Potato (*Solanum tuberosum*) hold a front position in the culinary legacies across many communities in the world. Despite its Andean origins, where it was first domesticated over 8,000 years ago, the crop had undergone continuous evolutionary development (Parra-Rondinel *et al.* 2021). Archaeological evidence indicates that potato tubers were consumed even before the advent of modern agriculture (Bradeen *et al.* 2011), which means potatoes had been cultivated naturally, and over time, the crop evolved to become a major global non-cereal staple due to its exceptional adaptability across diverse geographies, latitudes, and altitudes (Campos and Ortiz, 2020). Given, the richness of the several essential nutrients, demand for potato is increasing in many developing countries in Africa and Asia as well (Devaux *et al.* 2020). The significance and popularity of the potato

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are also reflected in cultural works such as Vincent van Gogh's painting "The Potato Eaters" and poem "Ode to the Potato", composed by Pablo Neruda, the Nobel Laureate in Literature (Campos and Ortiz, 2020). It is the most important vegetable crop in India which contributes nearly one-third of the country's total vegetable production and remains a key component of the Indian vegetable basket (Singh *et al.* 2009; Directorate of Economics and Statistics, 2022).

India successfully leveraged its diverse agro-climatic conditions following the introduction of the potato by the Portuguese in the 17th century and subsequently emerged as the second-largest producer globally, after China. Potatoes were cultivated in more than 154 countries, with global production reaching approximately 383 million tonnes. China ranked first with a production of 93.49 million tonnes, followed by India with 60.14 million tonnes (Hu *et al.* 2025) which was cultivated on 2.25 million hectares, achieving an average productivity of 24.12 tonnes per hectare and contributing 14.41 per cent to global output (FAO, 2023).

The North Eastern region (NER) of India, encompassing the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, exhibits considerable potential for potato cultivation. This potential is attributed to its varied topography, fertile soils rich in organic matter, and agro-climatic conditions favourable for crops (Prakash *et al*. 2019). Since the time immemorial, communities in the North Eastern Hill region NEHR has been traditionally practicing agriculture based on the generational indigenous farming knowledge under natural conditions without the use of agrochemicals (Athawale and Singh, 2023), reflecting an inherent alignment with the principles of natural farming such as zero or minimum tillage, intercropping, mixed-cropping, mulching, crop rotation, no use of agrochemicals, crop diversity thereby fostering functional biodiversity (Athawale *et al.* 2024). In the NEHR, potato plays a crucial role in the cropping systems and dietary habits of the region's inhabitants (Sah *et al.* 2011; Singh *et al*. 2017). The NER contributed about 6.1 per cent of the total area under potato in the country. The crop is grown throughout the year in the NEHR under rainfed condition, grown in *summer* (February to June-July) and *autumn* (July-August to November-December) at higher elevation, whereas in valley and plains, it is grown as a *rabi* crop in the winter (Sailo *et al.* 2024). Most of the farmers were practicing traditional way of cultivation *i.e.* '*Bun* and *Nur* 'method in Meghalaya; in marginal land with minimum inputs and formed an integral part of prevailing cropping systems in the region (Sah *et al.* 2006; Kumar *et al.* 2006). Local potato varieties in Meghalaya, such as *Lah Taret, Lah Saw Khasi, Lah Polin, Lah Sarkari*, and *Lah Saw Smit*, had been cultivated particularly for their taste and primarily used for home consumption (Rajavardhan *et al.* 2021). Additionally, in the region also cultivate high yielding varieties such as; *Kufri Girdhari, Kufri Giriraj, Kufri Himalini, Kufri Jyoti, Kufri Megha, Kufri Khasi-Garo,* and *Kufri Shailja*, along with inorganic inputs to enhance yields and returns. Previous studies in various agro-climatic zones have explored the comparative economics of natural farming *vs* conventional farming (relies on the synthetic inputs) (Koner and Laha, 2020; Jessica *et al.* 2021; Laishram *et al.* 2022; Khan *et al.* 2023; Duddigan *et al.* 2023; Chauhan *et al*. 2023;). The focus of these investigations was limited on the main land and South India, where the predominant models such as, of Zero Budget Natural Farming (ZBNF), Andhra Pradesh Community Managed Natural Farming (ANCMNF), Subhash Palekar Natural Farming (SPNF) *etc.* are prevalent. Whereas, limited studies have been conducted on the comparative economics of natural and conventional farming in the NEHR context. It is imperative to recognize that these models of natural farming may not be directly applicable to the unique agricultural system of the NER of India (Athawale *et al.* 2024). With this background, the present study has been undertaken to fill this research gap by analyzing the performance of potato grown under the natural *vis-à-vis* conventional farming in the state of Meghalaya including the resource productivity of potato.

METHODOLOGY

Sampling Plan

The study was conducted in the state of Meghalaya, region of NER of India. Central Potato Research Station (CPRS), Shillong indicated that the potato crop occupies an estimated 10,000 to 12,000 hectares in Meghalaya, yielding between 120,000 and 150,000

tonnes annually (CPRI, 2022). *Ri-Bhoi*, West Garo Hills and West Jaintia Hills were purposively selected due to its reliance on agriculture as the primary livelihood of its inhabitants. For the study, the Bhoirymbong, Rongram, Lashein blocks were selected from *Ri-Bhoi*, West Garo Hills and West Jaintia Hills, respectively. From each block two villages were selected purposively- From Bhoirymbong, Mawhrydep and Mawbri; from Rongram, Eden Bari and Pagugre; and from Lashein block, Khliehrangnah and Mynska were selected. To mitigate non-representative sampling issues, a minimum of 10 per cent of households in each village were sampled. The sample consisted of 56 natural and 34 conventional farmers selected through snowball sampling method. During data collection, it had been observed that, all respondents from West Garo Hills District fully practice natural farming. Natural farming respondents were defined as those who adhered to practices such as minimal tillage, abstaining from agro-chemical usage, implementing mulching, adopting crop rotation, and practicing polycropping. Conversely, farmers not following these attributes were categorized as conventional farmers. Primary data were collected from the sample respondent through personal interview on a well-structured schedule comprising of land preparation, human and animal labour cost, transplanting cost, plant protection, machinery use, harvesting, threshing, various implements used by the respondents and yield *etc*. were collected pertaining for the agricultural year 2023-24. Simple descriptive statistics and t test was carried out to know the significant difference between the natural farming and conventional farming.

Analytical tools and techniques

Compound annual growth rate

Secondary data was obtained from FAOSTAT 2024 (2001-2022), Directorate of Economics and Statistics (DES) (India: 2001-2022), Government of Meghalaya (2000–01 to 2019–20). The area, production and productivity of potato were examined by estimating the compound annual growth rate using the formula below:

$$Y_t = ab^t$$

Where, Y_t is the area and production of major crops, a is the constant, b is the regression coefficient and t is the time variable.

After log transformation and estimation of the equation;

$$ln\ Y_t = lna + tln_b$$

The compound annual growth rate was estimated as;

$$G = (antilog\ (ln\ b) - 1) \times 100$$

Cost and return

In order to work out the economics of natural farming *vis-à-vis* conventional farming the cost of production of the cultivated crops and cropping system was computed using cost concepts proposed by the Special Expert Committee.

Commission for Agricultural Costs and Prices Cost Concepts

Cost A_1 includes:

(i) Cost of planting material cost
(ii) Cost of manures, fertilizers, and pesticides
(iii) Cost of hired human labour
(iv) Cost of owned and hired bullock labour
(v) Cost of owned and hired machineries
(vi) Depreciation on implements, farm buildings, and irrigation structures
(vii) Land revenue
(viii) Interest on owned working capital

Cost A_2: Cost A_1 + rent paid for leased-in land

Cost B_1: Cost A_1 + interest on the fixed capital assets excluding land

Cost B_2: Cost B_1 + rental value of owned land

Cost C_1: Cost B_1 + imputed value of family labor

Cost C_2: Cost B_2 + imputed value of family labor

Analysis of economic returns

The net returns over different cost concepts was calculate as the difference between the gross farm income (GFI) and particular cost as follows: -

Gross farm income (GFI) = Value of main product

Net return including family labour = GFI − Total cost including family labour

Net return excluding family labour = GFI − Total cost excluding family labour

Farm business income = GFI – Cost A_2

Family level income = GFI − Cost B_2

Net farm income = GFI – Cost C_2

Farm investment income = Farm business income – Wages of family labour.

Benefit cost ratio (BCR)

Benefit cost ratio of an investment is the ratio of the discounted value of all cash inflows to the discounted value of all cash outflows during the life of the crop or project. The benefit cost ratio was worked out by using following formula;

$$BCR = \frac{\sum_{t=0}^{T} R_t / (1+i)^t}{\sum_{t=0}^{T} C_t / (1+i)^t}$$

Where,

R_t = GFI in period t

C_t = Cost C_2 in period t

If the Benefit cost ratio is greater than unity, the investment is profitable.

Resource Productivity

Functional form for the natural farming is as specified as:

$$Y = f(X_1, X_2, X_3, X_4) \quad \ldots(1)$$

Y = Net return, X_1 = value of planting material per hectare in rupee, X_2 = wage of the human labour in rupee, X_3 = value of FYM in rupee.

Functional form for the conventional farming is as specified as:

$$Y = f(X_1, X_2, X_3, X_4, X_5) \quad \ldots(2)$$

Y = Net return, X_1 = value of planting material per hectare in rupee, X_2 = value of plant protection per hectare in rupee, X_3 = wage of the human labour in rupee, X_4 = value of machine labour in rupee, X_5 = value of bullock labour in rupee.

Linear, semi-log, double-log (Cobb-Douglas) these three functional forms were fitted and estimated using the Ordinary Least Squares (OLS) technique. The lead equation was chosen on the basis of the values of the coefficient of multiple determination (R^2). Double-log production function was found to be the best fit hence it was preferred over other production function.

Allocative efficiency

Allocative efficiency (AE) was determined by calculating the ratio of the marginal value product (MVP) to the marginal factor cost (MFC);

$$AE = MVP/MFC$$

$$MVP = MPP_i * P_y$$

Where, MVP = Marginal value product, MPP_i = Marginal physical product of the i^{th} input,

P_y = Price of output

$$MPPi = bi*Y/Xi$$

where, bi = Elasticity coefficient of the i^{th} independent variable, Y = Geometric mean of the output, Xi = Geometric mean of the i^{th} input.

RESULTS AND DISCUSSION

During the time period 2001–02 to 2020–21, a positive growth trend was observed in the production, and productivity of potato at both the global and national levels (Table 1). At the global level, the area under potato cultivation exhibited a decline of 0.31 per cent per annum, whereas production and productivity showed a significant positive growth rate of 1.18 per cent and 1.49 per cent, respectively, at the 1 per cent level of significance. In contrast, India recorded a substantial increase in all three parameters. The area under cultivation expanded at 2.77 per cent, production at 4.46 per cent, and yield at 1.65 per cent per annum, all statistically significant at the 1 per cent level. This underscores India's consistent growth in both input (area) and efficiency (yield), with the growth in production outpacing the global average considerably. At the state level,

Meghalaya exhibited a positive annual growth in area and production at 1.69 per cent and 1.32 per cent, respectively, both significant at the 1 per cent level. However, the state experienced a decline in productivity by 0.36 per cent per annum, which was not statistically significant, suggesting the gains in production are largely area-driven rather than yield-based. At the district level, a more granular analysis revealed that *Ri-Bhoi* district experienced impressive growth in area (3.68%), production (5.02%), and productivity (1.29%), all significant at the 1 per cent level, indicating a favourable environment for potato cultivation. On the other hand, West Garo Hills showed a decline in both area (1.27%) and production (1.26%), significant at the 10 per cent level, while the productivity remained nearly stagnant at 0.01 per cent, highlighting stagnation and possible constraints in cultivation (Table 1).

Table 1: Growth rate of different performance indicators of potato

	CAGR(%)		
	Area	**Production**	**Yield**
World	-0.31***	1.18***	1.49***
India	2.77***	4.46***	1.65***
Meghalaya	1.69***	1.32***	-0.36
Ri- Bhoi	3.68***	5.02***	1.29***
West Garo Hills	-1.27*	-1.26*	0.01

**Significant at 10% probability level, **Significant at 5% probability level, ***Significant at 1% probability level. Source: Authors' computation based on the data from FAOSTAT 2024 (2001-2022), Directorate of Economics and Statistics (DES) (India: 2001-2022), Government of Meghalaya (2000–01 to 2019–20).*

Comparative labour requirement

Table 2 reveals significant differences in the use of human labour under natural farming compared to conventional farming for potato cultivation. The analysis distinctly accounts for male and female contributions in both hired and family labour, reflecting potential gender-specific involvement and variations in labour demands between the two farming system. In the case of hired labour, male labour under natural farming was reported at 25.74 days per hectare, representing 22.14 per cent of total labour use. Comparatively, conventional farming employed 24.37 male labour days per hectare (23.84%), indicating a 5.62 per cent higher male hired labour use in natural farming. For female hired labour, the requirement was found to be 28.81 days per hectare (24.78%) in natural farming, whereas conventional farming reported 23.34 days per hectare (22.84%). This shows a 23.46 per cent higher utilization of female hired labour in natural systems, emphasizing the relatively greater engagement of women under ecologically-oriented practices. Regarding family labour, male family labour in natural farming accounted for 30.39 days per hectare (26.14%) against 25.03 days per hectare (24.50%) in conventional farming, with a 21.42 per cent increase over conventional practices. This indicates greater reliance on male household members under natural conditions, possibly due to lower mechanization and increased manual interventions.

Table 2: Comparative labour requirement in natural and conventional farming in Meghalaya

Particulars	**Natural Farming**	**Conventional Farming**	**Percent difference (over conventional farming)**
Hired labour (days/ha)			
Male	25.74	24.37	5.62
	(22.14)	(23.84)	
Female	28.81	23.34	23.46
	(24.78)	(22.84)	
Family labour (days/ha)			
Male	30.39	25.03	21.42
	(26.14)	(24.50)	
Female	31.32	29.45	6.32
	(26.94)	(28.82)	
Total human labour (days/ha)			
Male	56.13	49.40	13.63
	(48.28)	(48.34)	
Female	60.13	52.79	13.89
	(51.72)	(51.66)	
Total	**116.26**	**102.19**	13.76
	(100.00)	(100.00)	

Source: *Authors calculation based on field survey 2023-24.*

Note: *Figures in parentheses are the percentage to the total.*

Similarly, female family labour under natural farming stood at 31.32 days per hectare (26.94%), marginally higher than 29.45 days per hectare (28.82%) observed in conventional farming,

rendering to a 6.32 per cent increase. Although the proportional difference was less than that of male labour, the data still points to higher female participation under natural farming regime. When assessing total human labour, which includes both hired and family labour, male labour days under natural farming amounted to 56.13 per hectare (48.28%) as compared to 49.40 days per hectare (48.34%) in conventional systems indicating a 13.63 per cent increase. Meanwhile, total female labour was 60.13 days per hectare (51.72%) under natural farming and 52.79 days per hectare (51.66%) in conventional farming, resulting in a 13.89 per cent increase in favour of the natural approach. Given the matrilineal social structure of the state of Meghalaya, female participation in the agricultural operations was often overlooked (Sah *et al.* 2007). In aggregate, natural farming systems utilized 116.26 total labour days per hectare, compared to 102.19 labour days per hectare in conventional systems registering a 13.76 per cent higher labour requirement. This supports the conclusion that natural farming is more labour-intensive than conventional methods. The greater need for manual operations such as mulching, weeding, and organic input application largely explains this difference.

Comparative cost of rice production

The Table 3 showed the comparison of the cost of cultivation of potato in natural farming *vs* conventional farming. Seeds and human labour were found to be the major cost components in both farming systems, constituting 37.94 per cent and 24.20 per cent in natural farming and 37.58 per cent and 22.00 per cent in conventional farming, respectively. The cost of seed (vegetative planting material) was 3.35 per cent lower in natural farming (₹ 29531.07/ha) compared to conventional farming (₹ 30554.87/ha) as natural farmers typically saved tubers from previous seasons using traditional storage structures for both short and long-term use (Sah *et al*. 2009). In contrast, conventional farmers primarily use high-yielding hybrid varieties alongside indigenous varieties. Since natural farming was often practiced on smaller plots for family consumption, all cultivation activities from seedbed preparation to harvesting were reportedly done manually. In contrast, conventional farmers utilized machine labour for land preparation and making bunds. Furthermore, the use of bullock labour was not reported, because of the undulating and small potato plots.

Table 3: Comparative economics of potato farming in Meghalaya (₹/ha)

Cost items	Natural Farming	Conventional Farming	Percent difference (over conventional farming)
Planting material	29531.07 (37.94)	30554.87 (37.58)	-3.35
Hired labour	18833.50 (24.20)	17885.79 (22.00)	5.30
Machine Labour	—	4000.00 (4.92)	-100.00
FYM	1114.11 (1.43)	2544.86 (3.13)	-56.22
Fertilizers		2152.42 (2.65)	-100.00
Depreciation	178.06 (0.23)	216.59 (0.27)	-17.79
Land revenue	—		
Interest on working capital @4 %	1986.27 (2.55)	2294.18 (2.82)	-13.42
Cost A_1	51643.01 (66.36)	54275.86 (66.76)	-4.85
Cost A_2	51643.01 (66.36)	54275.86 (66.76)	-4.85
Interest own fixed assets	179.39 (0.23)	2320.40 (2.85)	-92.27
Cost B_1	51822.40 (66.59)	56596.26 (69.61)	-8.43
Rental value of own land	4311.71 (5.54)	4292.92 (5.28)	0.44
Cost B_2	56134.11 (72.13)	60889.18 (74.89)	-7.81
Imputed value of family labour	21693.69 (27.87)	20414.41 (25.11)	6.27
Cost C_1	73516.09 (94.46)	77010.67 (94.72)	-4.54
Cost C_2	77827.80 (100.00)	81303.59 (100.00)	-4.28

Note: *Figure in parentheses are percentage of total Cost* C_2

Source: *Field survey, 2023-24.*

Given the labour-intensive practices in natural farming, the cost incurred in hired labour was

higher in natural farming (5.30%). Similarly, the cost of Imputed value of family labour was obtained to be more in the natural farming by 6.27 per cent. The percentage difference in key cost components showed that there was 100 per cent cost saving in machine labour and fertilizers under natural farming. Interestingly, no pesticide usage was reported in conventional farming which could likely be attributed to the practice of crop rotation in both farming system. Crop rotation is a potential strategy for managing pests and diseases, helping to reduce the need for chemical interventions (Wu *et al.* 2010). After harvesting of potatoes, natural farmers typically grow vegetables such as peas, cabbage, cauliflower, mustard, and maize aligning with the crop sequences reported by Pandey *et al.* (2008). Land revenue was reported to be zero in the region. The cost of cultivation under Cost A_2 was ₹ 51,643.01 per hectare in natural farming and ₹ 54,275.86 per hectare in conventional farming, which was marked by 4.85 per cent reduction. Potato cultivation under the natural farming regime showed a reduction of 4.28 percent in the total cost of cultivation compared to conventional farming practices. Specifically, the Cost C_2 per hectare amounted of ₹ 77,827.80 under natural farming, *vs* of ₹ 81,303.59 under conventional farming.

Comparative returns of potato farming in Meghalaya

The Table 4 revealed the comparison of income and profitability from potato farming under natural farming *vs* conventional farming. The yield under natural farming was of 6505.00 kg per ha, which was lower than conventional farming (7025.66 kg/ha), with a difference of 520.66 kg per ha. However, the gross farm income was slightly higher in natural farming at ₹ 1,77,064.70 per hectare compared to ₹ 1,75,641.56 per hectare in conventional farming, indicated a marginal increase of ₹ 1,423.13. The returns including family labour were ₹ 99,236.90 per hectare in natural farming and ₹ 94,337.97 in conventional farming, with a positive difference of ₹ 4,898.93. The benefit-cost (BC) ratio was 2.28 under natural farming, while it was 2.16 under conventional farming, indicating that natural farming was economically efficient giving 0.11 more in returns for every rupee invested. This indicated that despite slightly lower yields, natural farming generated higher returns and profitability compared to conventional farming.

Table 4: Comparative returns of potato farming in Meghalaya

Cost items	Natural Farming	Conventional Farming	Mean difference
Yield (kg/ha)	6505.00	7025.66	-520.66
Gross Farm Income (GFI)	177064.70	175641.56	1423.13
Returns including family labour (GFI-Cost C2)	99236.90	94337.97	4898.93
Returns excluding family labour (GFI-Cost B2)	120930.58	114752.38	6178.20
Farm Business income (GFI-Cost A2)	125421.68	121365.70	4055.98
Farm investment income (GIF-(Cost A2 + imputed value of family labour)	103727.99	100951.29	2776.70
BC Ratio	2.28	2.16	0.11

Source: *Field survey, 2023-24.*

Paul *et al.* (2023) observed that potato grown under organic farming practices showed improved growth and yield, likely due to the application of nutrient-rich inputs like vermicompost, FYM and *panchagavya*, supplemented with of bio-fungicides. Tein (2015) and Chauhan *et al.* (2023) observed that in conventional potato farming, combining inorganic inputs with recommended fertilizer doses and FYM resulted in higher yields and improved crop quality compared to natural farming. These studies collectively indicated that providing adequate nutrition played an important role in achieving higher yields.

Comparison of paid out cost

The cost differences are presented in Table 5, showed that the cost accounted for human labour in natural farming was significantly higher than the cost incurred in conventional farming, with a mean difference of ₹ 2,226.98 per hectare, which was significant at 1 per cent level of significant. The mean differences in planting material, FYM, machine labour, and fertilizers were also notable. The cost of FYM in natural farming was lower than in conventional farming, with a mean difference of ₹ 1,430.75 per hectare, which was also significant at

1 per cent level of significance. Similarly, the cost of fertilizers was completely eliminated in natural farming, resulting in a cost saving of ₹ 2,152.42 per hectare. A reduction in machine labour cost by ₹ 4,000.00 per hectare was also observed in potato natural farming.

Table 5: Results of unpaired t-test paid out cost

Inputs	Natural Farming	Conventional Farming	Mean difference	t-value
Planting material	29531.07	30554.87	-1023.80	1.01
Human labour	40527.19	38300.21	2226.98	4.88***
Machine labour	—	4000.00	-4000.00	—
FYM	1114.11	2544.86	-1430.75	9.66***
Fertilizers	—	2152.42	-2152.42	—

Note: **** significant at 1 per cent.*

Source: *Field survey, 2023-24.*

This may be because potato natural farmers predominantly rely on human labour for all the farming operations and locally available resources, such as cow dung application along with crop rotation to meet crop nutrient requirements. The major cost component in potato was found to be seed followed by human labour and manures and fertilizers, plant protection as reported by Pandey *et al.* (2001). Additionally, human labour, encompassing both hired and family labour, constituted a significant portion of the total variable costs (Venyo and Sharma, 2018; Yadav *et al.* 2024).

The yield and return differences are presented in Table 6, which showed that the yield under natural farming was significantly lower than under conventional farming, with a mean difference of 520.66 kg per hectares, significant at the 1 per cent level. However, gross returns were slightly higher under natural farming, though the difference of ₹ 1,423.13 per hectare was not found to be statistically significant Net returns which demonstrate the profitability after deducting total cost, were also higher in natural farming by ₹ 4,898.93 per hectare, and the difference was statistically significant at 10 per cent. These results suggested that despite lower yield, potato natural farming maintained competitive returns, possibly due to reduced input costs. Numerous studies conducted globally on the economics of potato farming have identified the potato crop as a highly lucrative enterprise (Khan and Akhtar, 2006; Gondalia *et al.* 2017; Subedi *et al.* 2019; Sinha and Singh, 2019; Alamgir *et al*. 2020; Kumari and Maurya, 2023; Yadav *et al.* 2024).

Table 6: Results of unpaired t test of returns from natural and conventional farming

Particulars	Natural Farming	Conventional Farming	Mean difference	t-value
Yield (Kg/ha)	6505.00	7025.66	-520.66	32.56***
Gross returns (₹/ha)	177064.70	175641.56	1423.13	0.81
Net returns (₹/ha)	99236.90	94337.97	4898.93	1.55*

Note: **** significant at 1 per cent; * significant at 10 per cent.*

Source: *Field survey, 2023-24.*

Resource use efficiency

The estimated double log Cobb-Douglas production function for potato cultivation is presented in Table 7. The resource productivity of inputs under natural farming revealed that planting material and human labour were statistically significant at 1 per cent level. A one per cent increase in the cost of planting material, keeping other factors constant, would result in a 0.41 per cent decrease in total value of production, while a one per cent increase in human labour cost would increase output by 2.01 per cent. Farmyard manure (FYM) was positively significant at 10 per cent level, indicating that a per cent increase in its use would result in 0.87 per cent increase in output. The coefficient of multiple determination (R^2) was 0.16, suggesting that 16 per cent of the variation in potato output under natural farming was explained by the included variables. Similarly, in potato conventional farming planting material was negatively significant at 1 per cent level, where a one per cent increase in cost would reduce the output by 1.03 per cent. FYM was positively significant at 5 per cent level, contributing to a 3.20 per cent increase in output with a one per cent increase in cost. However, human labour, machine labour, and fertilizers were found to be statistically insignificant. The R^2 value was 0.59, indicating that 59 per cent of the variation in output under conventional farming was explained by the

selected inputs. The remaining variation might be due to the other variables which is considered in the model. Khan *et al.* (2020) similarly reported that increased human labour contributed to higher returns in potato farming in Pakistan. Similarly, Sinha and Singh (2023) found that manure and fertilizer had a positive and statistically significant effect on potato production in the Northern Hills of Chhattisgarh, while Mdoda *et al.* (2023) reported contrasting results from the potato production in Eastern Cape Province of South Africa.

Table 7: Resource productivity of potato in Meghalaya

Variables	Coefficients		Standard Error		P-value	
	NF	CF	NF	CF	NF	CF
Intercept	12.03***	3.36	1.38	2.86	0.39	0.01
Planting material	-0.41***	-1.03***	0.16	0.27	0.01	0.00
Human labour	2.01***	0.72	0.23	0.68	0.01	0.29
Machine labour		-0.77		0.81		0.35
FYM	0.87*	3.20**	0.56	1.84	0.13	0.05
Fertilizers		2.95		3.87		0.45
R^2	0.16	0.59				

***Note:**, *** p<0.01, ** p<0.05, *p<0.1, respectively; NF- Natural Farming, CF- Conventional Farming.*

***Source:** Field survey, 2023-24.*

Allocative efficiency

Allocative efficiency shows how responsive farmers are to the price changes. When the value of allocative efficiency is below 1, it suggests over utilization of particular input. Therefore, reducing that particular input use could lead to increased profits. In contrast, a value of allocative efficiency above 1, implied to under-utilization of the resource. On this account, there is room for increasing its application. An allocative efficiency value of 1 indicates optimal resource use which means the resource is being utilized efficiently.

Allocative efficiency ratios of key inputs in potato farming within the state of Meghalaya were computed and are presented in Table 8. FYM showed significant potential for further utilization, as the efficiency ratio is greater than one for natural farmers (1.26) as well as conventional farmers (1.30), implying that an augmentation in FYM usage could result in increased production. Similarly, efficiency of human labour (1.20) was more than 1 for natural farming. Conversely, planting material exhibited ratios below unity indicating their overutilization under natural farming (1.35) as well as conventional farming (1.71). A reduction in the usage of planting material would consequently contribute to profit maximization among the surveyed natural farming households. This indicated that optimizing input use, particularly reducing excessive planting material and enhancing FYM application, could improve profitability in both farming systems. Multiple studies on efficiency of various inputs on the potato cultivation were reported mixed findings on various locations (Sujan *et al.* 2017; Sapkota and Bajracharya, 2018; Sinha and Singh, 2023; Upadhyay, 2024).

Table 8: Allocative efficiency of potato in Meghalaya

Variables	Coefficients		MVP		MFC		MVP/MFC	
	NF	CF	NF	CF	NF	CF	NF	CF
Planting material	-0.41	-1.03	-37.03	-61.39	27.50	36.00	-1.35	-1.71
Human labour	2.01	—	540.45	—	450.00	—	1.20	—
FYM	0.87	3.2	1550.37	2932.87	1230.00	2250.00	1.26	1.30

***Source:** Field survey, 2023-24.*

CONCLUSION

The comparative analysis of potato cultivation under natural and conventional farming in the state of Meghalaya revealed distinct economic results. Natural farming involves significantly higher human labour days compared to conventional farming, which lead to the high labour costs compared to conventional farming. However, natural farming involves significantly reduced costs in planting material and FYM, whereas, potato natural farming saves cent per cent cost on machine labour, and fertilizers compared to conventional

farming. Therefore, there was significant net return in natural farming compared to conventional farming. In terms of inputs utilization, there is still scope for increasing the usage of various inputs such as FYM and Human labour, in order to increase the production and productivity of potato in the region. The study also showed the notable gender-based variations in labour requirements, concluding natural farming as labour intensive farming. In both natural and conventional farming, the per cent of total female labour utilization was observed to be little higher than total male labour. This observation emphasized the integral role of women in agricultural activities in the region. The study suggests that, the farmers of other regions within the state or region can also be encouraged to grow crops naturally, which could improve farmer's incomes and healthy livelihoods, while reduce environmental degradation and yield long-term sustainability.

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