Decomposition Analysis of Mango Production by Adopting Good Agricultural Practices in Tamil Nadu

B. Kavitha[1*] and M. Uma Gowri[1]

[1]*Department of Agricultural Economics, Centre for Agriculture and Rural Development Studies,*
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 641003, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author BK conceived the main idea and designed the model. Authors BK and MUG involved in data collection through field survey. Author BK processed the experimental data. Both authors performed the analysis. Author MUG oversaw the findings of this work. Author BK drafted the manuscript. Both authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Adoption of Good Agricultural Practices (GAP) aids in endorsing optimum utilization of resources with eco-friendly agriculture to ensure safety supply of food. This study was carried out to apply decomposition analysis for segmenting productivity changes due to adoption of good agricultural practices in mango cultivation. The output decomposition model was used for investigating the contribution of various constituent sources to the productivity difference between the GAP farming and the conventional methods of mango cultivation. The difference in technology contribution for total productivity variation alone was higher with 75.59 per cent and 93.17 per cent which could reveal that the farmers have obtained 75.59 per cent and 93.17 per cent more output per hectare by adopting good agricultural practices when compared to conventional borrowers and conventional non borrowers respectively. The contribution of differences in input use level to the productivity difference was meager at 11.40 per cent and 0.69 per cent for conventional borrowers and conventional non borrowers respectively. The mango farmers practicing good agricultural

_____

Corresponding author: E-mail: kavisribala@gmail.com;

practices obtained higher output by spending slightly more on the inputs compared to those practicing conventional method. Therefore, concentrated efforts needs to be made to encourage the farmers to adopt Good Agricultural Practices to get real eco-friendly benefits.

1. INTRODUCTION

India's contribution in agricultural exports at global level is progressively increasing whereas agro processing and agricultural exports are the crucial area in the country. As it was not fully utilized to its immense potential, Indian agriculture needs unceasing innovation and constant efforts to increase productivity, adoption of technology and infrastructure creation, processing and value-addition, post-harvest management to become a flourishing industry [1]. Indian agricultural produce has more incredible market opportunities at global level with some challenges imposed by World Trade Organization (WTO). It created new export prospects and new means for the farmers to earn higher prices for their produce [2]. The Agreement on Agriculture (AoA) provides pioneering opportunities for exporting both agricultural products and horticultural products. India is yet to make use of the emerging new opportunities to amplify its trade, particularly with the global market [3]. India is a prominent producer and exporter of mangoes to all other countries. India is exporting mango majorly in the form of mango pulp and exported 46510.27 MT of fresh mangoes to the world during the year 2018-19 [4]. Uttar Pradesh ranks first in mango production (4540.23 thousand MT) and also in productivity (17.1 MT/ha) during 2016-17. The main clusters of mango pulp in the country are Chittoor in Andhra Pradesh and Krishnagiri Tamil Nadu [5]. This market potential for agricultural produce can be attained by following food safety in production processes for gaining consumers satisfaction in the domestic trade and also for increasing global competitiveness in export of agricultural produce. With the vast agricultural productivity phenomena it becomes vital that the safety and quality of farm produce is ensured throughout the production process. Major achievements of food security and food safety need to be balanced concurrently. With these aspects, to facilitate farm produce to be internationally competitive, the concept of Good Agricultural Practices (GAP) in the background of commercial agricultural production is essential [6]. GAP are practices that includes recommendations and available knowledge to addressing economic, social and environmental sustainability for on-farm production and post production processes, resulting in safe and healthy food and non-food agricultural products [6]. Good agricultural practices, often combination of both good agricultural practices and effective input use, are one of the best ways to increase productivity and improve quality [7]. These practices are formally recognized in the international regulatory framework to improve yield and quality of the products, to reap environmental and social benefits by means of reducing risks associated with the use of plant protection chemicals, taking into account health, environmental and safety considerations [8]. Adoption of Good Agricultural Practices (GAP) aids in endorsing optimum utilization of resources with eco-friendly agriculture to ensure safety supply of food. It is an appropriate time to promote good agricultural practices in this period of reforming agriculture which is planned by Indian Government. The challenge today is to recast agriculture in the new environment of globalization, rising prices, growing domestic demand and greater private sector involvement. In addition, greater investment is also required to increase farmer's yield and profitability by using improved technologies. Many of the farmers are not in a situation to use improved seeds and manures or to introduce better methods or innovative techniques because of insufficient financial resources and absence of timely credit facilities at reasonable rates. There is also a positive association between credit to adopt innovative technologies and agricultural output but this phenomenon varies across states due to other variables determining production [9]. Hence, in India, the practice of systematic production of mango and processing has to be followed along with the capital. There is an urge to follow good agricultural practices in production, processing and marketing of Indian mangoes to attain economic, social and environmental sustainability. Keeping these things in the view, this study was carried out to apply decomposition model to find the output changes with respect to good agricultural practices adopted in mango cultivation.

2. METHODOLOGY

2.1 Sampling Design

The sampling design was carefully formulated to enable the study to deal with the impact of good agricultural practices. The sample mango farmers were classified as borrower farms and non-borrower farms. These two categories of mango farmers were adopting conventional mango cultivation practices. The third category of mango farmers was referred as GAP farmers who were adopting Good Agricultural Practices (GAP) and there were no farms without credit hence, purposively GAP farmers cum borrowers were selected. The total sample size was fixed at two seventy mango farms selected from the three identified blocks viz., Bargur, Kaveripattinam and Mathur based on mango production in the respective blocks. From each block, three villages were selected at random. For each of selected villages a sample of 30 mango growers which constituted 10 conventional borrowers, 10 conventional non-borrowers and 10 GAP farmers. The sample size of the conventional borrowers, conventional non-borrowers and GAP farmers were fixed at ninety from each block (Table 1).

2.2 Analysis

2.2.1 Decomposition analysis

The total change in productivity is decomposed in to changes due to technological practices and the input use. The output decomposition model as developed by Bisaliah was used for investigating the contribution of various constituent sources to the productivity difference between the GAP (Good Agricultural Practices) farming and the conventional methods of mango cultivation. The production function is widely used as the convenient model for disintegrating total change in output [10]. In the production function, the total output change is derived by shifts in the parameters that define the function and by changes in the volume of inputs. It is observed that there is difference between parameters of the production function generated by the new production technology and those generated by old technology; this implies a structural break in wheat production relations [11]. This result supports our rationale for decomposing the total change in output. The two results obtained that the decomposition analysis could be undertaken with Cobb – Douglas per hectare production function. Vietnam's rice quality had also considerably improved by investment to research. High Quality Rice was affected by changes in area, yield, and production [12]. The Cobb Douglas Production function is visibly a convenient economic frame work for testing the equality of parameters which governing the input–output relationships and for decomposing the total change in output. The growth rate of area under HQR, yield and production was 2.28 per cent, 1.72 per cent 4.03 per year for the study period 1995-2008. The total change in output per hectare due to technology effect was observed to be 14.12 per cent. Therefore, the production functions were considered as the convenient econometric tools for decomposing the productivity difference between the two methods of cultivation. In this analysis, there are three production functions for these three separate category farms. Firstly, GAP farms with conventional borrower farms and secondly, GAP farms with conventional non borrower farms were fitted to assess the impact of GAP on structural changes of mango production as follows and the variables taken for analysis are presented in the Table 2.

Table 1. Sample villages and mango farmers

Sl. no	Block	Village	Conventional borrowers	Conventional non-borrowers	GAP borrowers	Total
1.	Bargur	Kullanoor	10	10	10	30
		Pochampalli	10	10	10	30
		Kosapatti	10	10	10	30
2.	Kaveripattinam	Malathampatti	10	10	10	30
		Panagamutlu	10	10	10	30
		Kadhampatti	10	10	10	30
3.	Mathur	Kunnathur	10	10	10	30
		Rangampatti	10	10	10	30
		Sivampatti	10	10	10	30
	Total		90	90	90	270

Table 2. Details of variables used in decomposition analysis

Sl. no.	Categories/ Variables	GAP farms		Conventional borrower farms		Conventional borrower farms	
		Symbols	Co-eff.	Symbols	Co-eff.	Symbols	Co-eff.
1.	Age of the tree (Years)	X_{11}	a_1	X_{21}	b_1	X_{31}	c_1
2.	Farmyard Manure (tonnes /ha)	X_{12}	a_2	X_{22}	b_2	X_{32}	c_2
3.	Fertilizer (kg /ha)	X_{13}	a_3	X_{23}	b_3	X_{33}	c_3
4.	Plant Protection Chemicals (kg/ha)	X_{14}	a_4	X_{24}	b_4	X_{34}	c_4
5.	Labour (Man days)	X_{15}	a_5	X_{25}	b_5	X_{35}	c_5

In logarithm form, Cobb-Douglas production function for GAP farms,

$$lnY_{11} = ln\,a_0 + a_1\,ln\,X_{11} + a_2\,ln\,X_{12} + a_3\,ln\,X_{13} + a_4\,ln\,X_{14} + a_5\,ln\,X_{15} + u_1 \qquad ----\qquad (1)$$

Logarithm form of Cobb-Douglas production function for conventional borrower farms,

$$lnY_{21} = ln\,b_0 + b_1\,ln\,X_{21} + b_2\,ln\,X_{22} + b_3\,ln\,X_{23} + b_4\,ln\,X_{24} + b_5\,ln\,X_{25} + u_2 \qquad ---\qquad (2)$$

Logarithm form of Cobb-Douglas production function for conventional non borrower farms,

$$lnY_{31} = ln\,c_0 + c_1\,ln\,X_{31} + c_2\,ln\,X_{32} + c_3\,ln\,X_{33} + c_4\,ln\,X_{34} + c_5\,ln\,X_{35} + u_3 \qquad ----\qquad (3)$$

2.2.2 Decomposition analysis for gap farms with conventional borrower farms

Taking differences between (1) and (2) and adding some terms and subtracting the same terms.

$$lnY_{11} = ln\,a_0 + a_1\,ln\,X_{11} + a_2\,ln\,X_{12} + a_3\,ln\,X_{13} + a_4\,ln\,X_{14} + a_5\,ln\,X_{15} + u_1 \;------\qquad (1)$$

$$lnY_{21} = ln\,b_0 + b_1\,ln\,X_{21} + b_2\,ln\,X_{22} + b_3\,ln\,X_{23} + b_4\,ln\,X_{24} + b_5\,ln\,X_{25} + u_2 \qquad ---\qquad (2)$$

$$
\begin{aligned}
lnY_{11} - lnY_{21} = \ & (ln\,a_0 - ln\,b_0) + (a_1\,ln\,X_{11} - b_1\,ln\,X_{21}) + (a_2\,ln\,X_{12} - b_2\,ln\,X_{22}) + (a_3\,ln\,X_{13} \\
& - b_3\,ln\,X_{23}) + (a_4\,ln\,X_{14} - b_4\,ln\,X_{24}) + a_5\,ln\,X_{15} - b_5\,ln\,X_{25}) + u_1 - u_2 \;---\; -(4)
\end{aligned}
$$

$$
\begin{aligned}
ln\,(Y_{11}\,/\,Y_{21}) = \ & ln\,(a_0\,/\,b_0) + [a_1\,ln\,X_{11} - b_1\,ln\,X_{21} + (a_1\,ln\,X_{21} - a_1\,ln\,X_{21})] \\
& + [a_2\,ln\,X_{12} - b_2\,ln\,X_{22} + (a_2\,ln\,X_{22} - a_2\,ln\,X_{22})] + [a_3\,ln\,X_{13} - b_3\,ln\,X_{23} \\
& + (a_3\,ln\,X_{23} - a_3\,ln\,X_{23})] + [a_4\,ln\,X_{14} - b_4\,ln\,X_{24} + (a_4\,ln\,X_{24} - a_4\,ln\,X_{24})] \\
& + [a_5\,ln\,X_{15} - b_5\,ln\,X_{25} + (a_5\,ln\,X_{25} - a_5\,ln\,X_{25})] + u_1 - u_2 \\
= \ [ln\,(a_0\,/\,b_0)\,] \ & + [(a_1 - b_1)ln\,X_{21} + (a_2 - b_2)ln\,X_{22} + (a_3 - b_3)ln\,X_{23} + (a_4 - b_4)ln\,X_{24} \\
& + (a_5 - b_5)ln\,X_{25}] + [(a_1(lnX_{11}/\,lnX_{21}) + a_2(lnX_{12}/\,lnX_{22}) + a_3(lnX_{13}/\,lnX_{23}) \\
& + a_4(lnX_{14}/\,lnX_{24}) + a_5(lnX_{15}/\,lnX_{25})] + [\,u_1 - u_2]\; -----\qquad (5)
\end{aligned}
$$

2.2.3 Decomposition analysis for gap farms with conventional non borrower farms

Taking differences between (1) and (3) and adding some terms and subtracting the same terms.

$$lnY_{11} = ln\,a_0 + a_1\,ln\,X_{11} + a_2\,ln\,X_{12} + a_3\,ln\,X_{13} + a_4\,ln\,X_{14} + a_5\,ln\,X_{15} + u_1 \quad ----\qquad (1)$$

$$lnY_{31} = ln\,c_0 + c_1\,ln\,X_{31} + c_2\,ln\,X_{32} + c_3\,ln\,X_{33} + c_4\,ln\,X_{34} + c_5\,ln\,X_{35} + u_3 \qquad ---\qquad (3)$$

$$
\begin{aligned}
lnY_{11} - lnY_{31} = \ & (ln\,a_0 - ln\,c_0) + (a_1\,ln\,X_{11} - c_1\,ln\,X_{31}) + (a_2\,ln\,X_{12} - c_2\,ln\,X_{32}) + (a_3\,ln\,X_{13} \\
& - c_3\,ln\,X_{33}) + (a_4\,ln\,X_{14} - c_4\,ln\,X_{34}) + a_5\,ln\,X_{15} - c_5\,ln\,X_{35}) + u_1 - u_3 \;----\qquad (6)
\end{aligned}
$$

$$
\begin{aligned}
ln\,(Y_{11}\,/\,Y_{31}) \;=\;\; & ln\,(a_0\,/\,c_0) + [a_1\,ln\,X_{11} - b_1\,ln\,X_{31} + (a_1\,ln\,X_{31} - a_1\,ln\,X_{31})] \\
& + [a_2\,ln\,X_{12} - c_2\,ln\,X_{32} + (a_2\,ln\,X_{32} - a_2\,ln\,X_{32})] + [a_3\,ln\,X_{13} - c_3\,ln\,X_{33} \\
& + (a_3\,ln\,X_{33} - a_3\,ln\,X_{33})] + [a_4\,ln\,X_{14} - c_4\,ln\,X_{34} + (a_4\,ln\,X_{34} - a_4\,ln\,X_{34})] \\
& + [a_5\,ln\,X_{15} - c_5\,ln\,X_{35} + (a_5\,ln\,X_{35} - a_5\,ln\,X_{35})] + u_1 - u_3 \\
= [ln\,(a_0\,/\,c_0)] + & [(a_1 - c_1)ln\,X_{31} + (a_2 - c_2)ln\,X_{32} + (a_3 - c_3)ln\,X_{33} + (a_4 - c_4)ln\,X_{34} \\
& + (a_5 - c_5)ln\,X_{35}] + [(a_1(lnX_{11}/\,lnX_{31}) + a_2(lnX_{12}/\,lnX_{32}) + a_3(lnX_{13}/\,lnX_{33}) \\
& + a_4(lnX_{14}/\,lnX_{34}) + a_5(lnX_{15}/\,lnX_{35})] + [u_1 - u_3] \quad -------- \quad (7)
\end{aligned}
$$

This is the decomposition model for decomposing the productivity difference between the GAP farming and conventional methods of mango cultivation. The equations (5) and (7) involve decomposing the logarithm of ratio of per hectare productivity of GAP farming with conventional borrower farms and conventional non borrower farms of mango (LHS) respectively. This is approximately a measure of percentage change in per hectare output between GAP farming and conventional methods of cultivation. The first bracketed expression on the right hand side is a measure of percentage change in output due to shift in scale parameters (a_0, b_0, c_0) of the production function; the second bracketed expression, the sum of the arithmetic changes in output elasticities each weighted by the logarithm of the volume of that input used, is a measure of change in output due to shifts in slope parameters (output elasticities) of the production function; the third bracketed expression is the sum of the logarithms of the ratio, for each input, of 'GAP' to 'conventional' input, each weighted by the output elasticity of that input; this expression is measure of changes in output due to changes in quantities of the inputs per hectare used given the output elasticities of these inputs under GAP farming. In short, the summation of first and the second terms on the right hand side of the decomposition model together represented the productivity difference between the GAP farming and conventional methods of cultivation, attributable to the difference in the technological practices. The third term provided the productivity difference between the GAP farming and conventional methods of cultivation attributable to the differences in the input use.

2.2.4 Impact of gap with credit on yield in mango production

The decomposition analysis was performed to measure the relative contribution of area and yield towards the change in total production of different horticultural crops. The yield effects also played a dominant role for the growth in production for fruits during period III (2000-01 to 2010- 11) [13]. Another study conducted by Njuki and his co-workers was to quantify and to investigate the role of changing weather patterns in total factor productivity (TFP) fluctuations. TFP growth was decomposed into weather effects, technological progress, technical efficiency, and scale-mix efficiency changes. The parameter estimates of weather variables reveal that one percent increase in average temperature leads to a statistically significant 0.426% reduction in output. On the other hand, a one percent increase in precipitation leads to 0.026% increase in agricultural output. It is known that the approach helps to assess the role of different components responsible for TFP in agricultural productivity growth [14].

The technological factors represent good agricultural practices with credit are closely associated with technological progress. The decomposition analysis is approximately a measure of percentage change in output with the adoption of good agricultural practices with credit in the production process. Decomposition analysis was applied to measure the impact of Good Agricultural Practices by taking into account the conventional borrowers and conventional non borrowers. The results of the production function analysis and decomposition analysis of output differentials across of mango production in three different farm categories viz., GAP borrowing farms, conventional borrowing farms and conventional non borrowing farms are presented in the following section.

3. RESULTS AND DISCUSSION

3.1 Production Function Estimates in Mango Cultivation under Gap Borrower and Conventional Borrower Farms

Before partitioning the output into different components, the structural break in the estimated production functions was tested by using analysis of variance. The analysis is clearly indicated that the estimated production function parameters were significantly different from each other. This strongly supports the analysis of

output differentials into different components across production of mango. A log linear regression (Cobb–Douglas type) was estimated by the method of ordinary least square (OLS) method.

The estimated Cobb – Douglas production function for GAP Borrower Farms was

$$lnY_{11} = 0.58 + 0.28 \ln X_{11} + 0.38 ln X_{12} \\ + 0.11 ln X_{13} + 0.25 \ln X_{14} \\ + 0.33 \ln X_{15} - - - - - - \quad (8)$$

Substituting average values of corresponding independent variables in the above equation,

$$lnY_{11} = 0.58 + 0.28 (2.18) + 0.38(1.11) \\ + 0.11(2.52) + 0.25 (1.18) \\ + 0.33 (1.23) \\ lnY_{11} = 2.5885$$

The estimated Cobb – Douglas production function for Conventional Borrower Farms was

$$lnY_{21} = 0.37 + 0.14 \ln X_{21} + 0.17 ln X_{22} \\ + 0.16 ln X_{23} + 0.29 \ln X_{24} \\ + 0.15 \ln X_{25} - - - - \quad (9)$$

Substituting average values of corresponding independent variables in the above equation,

$$lnY_{21} = 0.37 + 0.14 (2.01) + 0.17(1.10) \\ + 0.16(2.48) + 0.29 (1.02) \\ + 0.15 (1.18)$$

Estimated $lnY_{21} = 1.7189$

The production function estimates have clearly indicated that the chosen factors of production have significantly influenced the production of mango both in GAP farm and conventional borrower farms (Table.3). It explained that 68 and 77 per cent variation in mango output due to variation in all the resources put together showing a good fit of the model in respective farms. It is further observed that most of the elasticity coefficients of inputs have registered the expected signs with a prior economic logic and found to be significant at respective probability levels. However, there were considerable differences in the extent of influence of different factors in mango production. In case of GAP farms, farm yard manure influenced the production significantly at 5 per cent level and followed by labour at 1 per cent significant level. The regression co – efficients of farm yard manure and labour

indicated that the mango yield would increase by 0.38 and 0.33 per cent for every one per cent increase in the use of FYM and labour respectively. Thus, the major contribution to output in GAP farms came from FYM and labour. Both number of saplings and plant protection chemicals were having more or less similar regression co-efficients. In this case, plant protection chemicals were not significantly influence the yield. The variable, fertilizer influenced the yield significantly with less value of co –efficient i.e. 0.11 which would increase the yield by only 0.11 per cent for every one per cent increase in the fertilizer.

In case of conventional borrower farms, plant protection chemicals influenced the dependent variable more at 10 per cent significant level when compared to other inputs in mango production. The co – efficient value of plant protection chemicals was 0.29 which described that change in output was majorly contributed by plant protection chemicals. Farm yard manure influenced the mango yield at 5 per cent significant level. Number of Saplings, fertilizer and labour were influenced the mango yield at 10 per cent significant level except fertilizer which was not significant. These four variables showed less contribution to the change in mango yield when compared to plant protection chemicals in this category of conventional borrower farms. It could be observed form the results that good agricultural practices need to be extended to those farmers who have not adopted so far, through extension activities and other measures. This would, on one hand, cut down the plant protection costs of GAP farmers and on the other, increase their mango yields through improved protection and efficient use of other resources. Therefore, concentrated efforts needs to be made to encourage the farmers to adopt good agricultural practices to get real benefits.

3.2 Sources Contributing to the Yield Differences

3.2.1 Decomposition of output change

Many researchers used this decomposition analysis like Mubbashira carried out for fruit crops in which changes in production mainly due to area expansion and yield. Production of citrus, mango and guava increased mainly due to area expansion, while improvement in production of minor fruits taken for the study was primarily due to yield parameter. While yield affect remained dominant in production of mango, guava and

minor fruits across decades during the period 1971-2016 [15]. The decomposition analysis of output growth of main crops such as wheat, barley, sugar beet and food grains studied by Shadmehri revealed that growth in production was mainly on account of change in yield. About 60 to 98.9 per cent growth in crop output was arisen due to yield effect. Production of rice (56.6 per cent), pulses, cotton (206.7 per cent), oilseeds and potato was increased due to expansion of area [16].

The percentage change in value of output has been decomposed into percentage change in output caused by GAP and percentage change in output caused change in per hectare use of other inputs. For decomposing the productivity difference between GAP borrower mango farms and conventional borrower mango farms, the parameters of the per hectare production functions and the mean levels of input use for the two methods were essential. Hence, the production functions for those two farms were also estimated separately. The productivity difference between the GAP farms and conventional farms mango production was decomposed into its constituent sources and the results are presented in Table 4.

Table 3. Cobb Douglas production function estimates in mango cultivation under gap borrower and conventional borrower farms

Sl. no	Variables	GAP borrowers		Conventional borrowers	
		Co – efficients	t value	Co – efficients	t value
1.	Intercept	0.58	1.72	0.37[*]	2.40
2.	Number of Saplings	0.28[*]	2.53	0.14[*]	2.16
3.	Farmyard Manure	0.38[**]	3.01	0.17[**]	3.35
4.	Fertilizer	0.11[*]	2.18	0.16[NS]	1.49
5.	Plant protection chemicals	0.25[NS]	1.64	0.29[*]	2.28
6.	Labour	0.33[***]	4.22	0.15[*]	2.54
	R Square	**0.68**		**0.77**	
	N	**90**		**90**	

ns – not significant

*** significant at 1 per cent level, ** significant at 5 per cent level and *significant at 10 per cent level respectively

Table 4. Decomposition of productivity difference between gap farms and conventional borrower farms

Sl. no.	Source of productivity difference	Percentage contribution
I	Total difference in output	86.96
II	Sources of contribution	
	A. Output difference due to Technology (1st & 2nd Bracket)	75.59
	B. Output difference Input use (3rd Bracket)	
1.	Number of sapling	4.82
2.	Farmyard Manure	0.58
3.	Fertilizer	0.48
4.	Plant protection chemicals	4.06
5.	Labour	1.46
	Due to all input use	11.40
	Total estimated change due to all sources (A + B)	86.99

While subtracting equations (8) and (9), LHS of the equality became as

$$lnY_{11} - lnY_{21} = 2.5884 - 1.7189 = 0.8696$$

RHS of the equality is

$$= [ln(a_0 / b_0)] + [(a_1 - b_1)lnX_{21} + (a_2 - b_2)lnX_{22} + (a_3 - b_3)lnX_{23} + (a_4 - b_4)lnX_{24}$$
$$+ (a_5 - b_5)lnX_{25}] + [(a_1(lnX_{11}/lnX_{21}) + a_2(lnX_{12}/lnX_{22}) + a_3(lnX_{13}/lnX_{23})$$
$$+ a_4(lnX_{14}/lnX_{24}) + a_5(lnX_{15}/lnX_{25})] ---- \qquad (10)$$

Substituting the respective values in the above equation,

$$
\begin{aligned}
= \{0.58 - 0.37\} + \{ & (0.28 - 0.14)\, lnX_{21} + (0.38 - 0.17)\, ln\, X_{22} + (0.11 - 0.16)\, ln\, X_{23} \\
& + (0.25 - 0.29)\, ln\, X_{24} + (0.35 - 0.15)\, ln\, X_{25}\} + \{0.28[(lnX_{11}/\, lnX_{21}] \\
& + 0.38\, [(lnX_{12}/\, lnX_{22})] + 0.11\, [(lnX_{13}/\, lnX_{23})] + 0.25\, [(lnX_{14}/\, lnX_{24})] \\
& + 0.33\, [(lnX_{15}/\, lnX_{25})]\} \quad - - - - - - - - - - - - - - \\
\end{aligned} \tag{11}
$$
$$= 0.2164 + 0.5394 + 0.1141 = 0.8699$$

The results of the decomposition analysis revealed that the total estimated change in the value output with the adoption of good agricultural practices worked out to 86.99 per cent. It is marginally higher than observed change in output (86.96) and there was not much discrepancy between these two values. The difference between the observed and estimated changes in output in both forms may be because of the non inclusion of certain factors, either due to the problem of quantification or due to non-availability of data. The net impact of adoption of GAP in mango cultivation can be captured by adding the first two bracketed expressions of Equation (11). Among the various sources responsible for total productivity variation, the difference in technology contribution alone was higher with 75.59 per cent. This could reveal that with some level of use of saplings, fertilizers, plant protection chemicals and human labour, the farmers have obtained 75.59 more output per hectare by adopting good agricultural practices when compared to those who have not adopting those practices. The contribution of differences in input use level to the productivity difference was meager at 11.40 per cent. This decomposition model had already been applied in estimating productivity changes in citrus cultivation also by Boubaker and his team-mates which cleared that the relative contribution of technical efficiency, technological change and increased input use to

the output growth of the Tunisian citrus growing farms was investigated by using decomposition model. It was found that the production was characterized by increasing returns to scale, which on average was 1.057. In that study, the sources of production growth reveal that the contribution of total factor productivity is found to be the main source of that growth [17]. Among the various inputs contributing to the productivity difference between GAP farms and conventional farms, number of saplings (4.82 per cent), farmyard manure (0.58 per cent), fertilizer (0.48 per cent) plant protection chemicals (4.06 per cent) and labour (1.46 per cent) contributed positively. This implied that mango farmers practicing good agricultural practices obtained higher output by spending slightly more on these two inputs compared to those practicing conventional method.

3.3 Production Function Estimates in Mango Cultivation under Gap Farms and Conventional Non Borrower Farms

The production functions for GAP borrower farms and conventional non borrower farms were also estimated separately and used for the decomposition analysis. A log linear regression (Cobb–Douglas type) was estimated by the method of ordinary least square (OLS) method.

The estimated Cobb – Douglas production function for GAP Borrower Farms was

$$lnY_{11} = 0.58 + 0.28\, ln\, X_{11} + 0.38ln\, X_{12} + 0.11ln\, X_{13} + 0.25\, ln\, X_{14} + 0.33\, ln\, X_{15} - - - - \tag{12}$$

Substituting average values of corresponding independent variables in the above equation,

$$lnY_{11} = 0.58 + 0.28\,(2.18) + 0.38(1.11) + 0.11(2.52) + 0.25\,(1.18) + 0.33\,(1.23)$$

$$lnY_{11} = 2.5885$$

The estimated Cobb – Douglas production function for Conventional Non Borrower Farms was

$$lnY_{31} = 0.32 + 0.15\, lnX_{31} + 0.05ln\, X_{32} + 0.14ln\, X_{33} + 0.41\, ln\, X_{34} + 0.06\, ln\, X_{35} - - - - - - \tag{13}$$

Substituting average values of corresponding independent variables in the above equation,

$$lnY_{31} = 0.32 + 0.15\,(2.13) + 0.05(1.09) + 0.14(2.94) + 0.41\,(1.17) + 0.06\,(1.15)$$

$$lnY_{31} = 1.6511$$

Estimated $lnY_{31} = 1.6511$

Table 5. Production function estimates in mango cultivation under gap farms and conventional non borrower farms

Sl. no	Variables	GAP borrowers		Conventional non borrowers	
		Co - efficients	t value	Co - efficients	t value
1.	Intercept	0.58*	1.72	0.32*	2.03
2.	Number of saplings	0.28*	2.53	0.15*	2.12
3.	Farmyard Manure	0.38**	3.01	0.05^{NS}	1.83
4.	Fertilizer	0.11*	2.18	0.14**	2.59
5.	Plant protection chemicals	0.25^{NS}	1.64	0.41^{NS}	1.76
6.	Labour	0.33***	4.22	0.06^{NS}	1.51
	R Square	**0.68**		**0.82**	
	N	**90**		**90**	

ns – not significant
*** significant at 1 per cent level, ** significant at 5 per cent level and *significant at 10 per cent level respectively

The estimated production function estimates are presented in Table 5. The production function estimates have clearly indicated that the chosen factors of production have significantly influenced the production of mango both in GAP farm and conventional non borrower farms by 68 and 82 per cent respectively. However, there were considerable differences in the extent of influence of different factors in mango production. The variable, number of sapling was found to influence the production significantly at 10 per cent in both categories of farms. In the conventional non borrower farms, plant protection chemicals placed the major contribution to influence the mango yield i.e. the application of plant protection chemicals by increasing one per cent resulted in 0.41 per cent increase in the yield. It was followed by number of saplings and fertilizer which accounted 0.15 per cent and 0.14 per cent at 10 per cent and 5 per cent significant level respectively. Similarly, farm yard manure and labour were influenced the yield with more or less same regression co – efficients viz., 0.05 and 0.06 respectively in the conventional non borrower farms. Therefore, Good Agricultural Practices need to be extended to those farmers who have not adopted so far, through extension activities and other measures. This would, on one hand, cut down the plant protection costs of GAP farmers and on the other, increase their mango yields through improved protection and efficient use of other resources. Therefore, concentrated efforts needs to be made to encourage the farmers to adopt Good Agricultural Practices to get real benefits.

3.4 Sources Contributing to the Yield Differences

3.4.1 Decomposition of output change

In order to evaluate the net impact of package of good agricultural practices and other inputs on mango productivity, the results of the decomposition analysis is presented in the Table 6. Hence, the productivity difference between the GAP borrower farms and conventional non borrower farms mango production was decomposed into its constituent sources. The percentage change in value of output has been decomposed into percentage change in output due to good agricultural practices and percentage change in output due to change in per hectare use of other inputs.

While subtracting equations (12) and (13), LHS of the equality became as

$$lnY_{11} - lnY_{31} = 2.5884 - 1.6483 = 0.9374$$

RHS of the equality is

$$= [ln(a_0 / c_0)] + [(a_1 - c_1)ln X_{31} + (a_2 - c_2)ln X_{32} + (a_3 - c_3)ln X_{33} + (a_4 - c_4)ln X_{34}$$
$$+ (a_5 - c_5)ln X_{35}] + [(a_1(lnX_{11}/lnX_{31}) + a_2(lnX_{12}/lnX_{32}) + a_3(lnX_{13}/lnX_{33})$$
$$+ a_4(lnX_{14}/lnX_{34}) + a_5(lnX_{15}/lnX_{35})] - - - - - - - \qquad (14)$$

Substituting the respective values in the above equation,

$$= \{0.58 - 0.32\} + \{(0.28 - 0.15)lnX31 + (0.38 - 0.05)ln X32 + (0.11 - 0.14)ln X33 +$$
$$(0.25 - 0.14)ln X34 + (0.35 - 0.06)ln X35\} + \{0.28[(lnX11/X31)] + 0.38[(lnX12/X32)] +$$
$$0.11[(lnX13/X33)] + 0.25[(lnX14/X34)] + 0.33[(lnX15/X35)]\} - - - - - - - - - - \qquad (15)$$

$$= 0.2597 + 0.6720 + 0.0069 = 0.9386$$

Table 6. Decomposition of productivity difference between gap farms and conventional non borrowers farms

SI. no.	Source of productivity difference	Percentage contribution
I	Total difference in output	93.74
II	Sources of contribution	
	A. Output difference due to Technology (1st & 2nd Bracket)	93.17
	B. Output difference Input use (3rd Bracket)	
1.	Number of saplings	1.48
2.	Farmyard Manure	0.97
3.	Fertilizer	-4.67
4.	Plant protection chemicals	0.31
5.	Labour	2.60
	Due to all input use	0.69
	Total estimated change due to all sources (A+B)	93.86

Total estimated productivity difference between the GAP borrower farms and conventional non borrower farms was estimated at 93.86 per cent which is marginally higher than observed change in output. Among the various sources responsible for total productivity variation, the difference in GAP contribution alone was higher with 93.17 per cent. This could reveal that with some level of use of saplings, farmyard manure, fertilizer, plant protection chemicals and labour, the farmers have obtained 93.17 per cent more output per hectare by adopting good agricultural practices when compared to those who have not adopted good agricultural practices.

Contribution of differences in input use level to the productivity difference was 0.69 per cent only. Among the various inputs contributing to the productivity difference between GAP farms and conventional non borrower farms, number of saplings (1.48 per cent), farmyard manure (0.97 per cent), plant protection chemicals (0.31 per cent) and labour (2.60 per cent) contributed positively except fertilizer (-4.67 per cent). This implied that mango farmers practicing good agricultural practices obtained higher output by spending slightly more on these four positive inputs compared to those practicing conventional method. Fertilizer used in conventional method of cultivation has helped to increase yield of mango by 4.67 per cent. Technological developments shift the production function up and to the right enabling the farmers to make greater use of yield increasing inputs. The findings of this analysis demonstrate the superiority of GAP in terms of yield and returns advantage. However, there is poor response of farmers to good agricultural practices due to lack of enough awareness among farmers about its superiority.

4. CONCLUSION

This is concluded that the mango farmers practicing good agricultural practices obtained higher output by spending slightly more on the inputs compared to those practicing conventional method. This would, on one hand, cut down the plant protection costs of GAP farmers and on the other, increase their mango yields through improved protection and efficient use of other resources. These practices shift the production function up and to the right enabling the farmers to make greater use of yield increasing inputs. The findings of this analysis demonstrate the superiority of GAP in terms of yield and returns advantage. Mango production with efficient use of resources and adoption of good agricultural practices fetched good return for the farmers in the study area. However, there is poor response of farmers to good agricultural practices due to lack of enough awareness among farmers about its superiority. Therefore, concentrated efforts needs to be made to encourage the farmers who have not adopted so far to adopt Good Agricultural Practices through extension activities and other measures to get real benefits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Agriculture Export Policy. Department of Commerce Ministry of Commerce and Industry Government of India; 2017. Available:https://commerce.gov.in/writerea ddata/uploadedfile/NTESCL636802085403 925699_AGRI_EXPORT_POLICY.pdf

2. Aijaz Ahmad Turrey. WTO agreements on agriculture and challenges for food security in India; 2018.
    Available:http://southasiajournal.net/wto-agreements-on-agriculture-and-challenges-for-food-security-in-india-2/
3. Manage. Training Programme on WTO and its implications on Indian agriculture, National institute of agricultural extension management (MANAGE). Rajendranagar, Hyderabad; 2013.
    Available:https://www.manage.gov.in/study material/WTO.pdf
4. Available:http://apeda.gov.in/apedawebsite /SubHead_Products/Mango.htm
5. National Mango Database; 2017.
    Available:http://mangifera.res.in/indianstat us.php
6. FAO. A scheme and training manual on Good Agricultural Practices (GAP) for fruits and vegetables. Food and Agriculture Organization of the United Nations. 2016;2:11.
    Available:http://www.fao.org/3/a-i6677e.pdf
7. Puja Dudeja, Amarjeet Singh. Good agricultural practices. Book chapter of food safety implementation: farm to fork. Publisher: CBS Publishers New Delhi. 2018;118-121.
    Available:https://www.researchgate.net/pu blication/329388995_Good_Agricultural_Pr actices/link/5c061c0e299bf169ae305421/d ownload
8. Ravishankar H, Misra AK. Good management practices for mango production and trade Technical Bulletin no. 41 .Central Institute for Subtropical Horticulture, Lucknow. 2010;2.
    Available:https://www.researchgate.net/pu blication/311738779_GOOD_MANAGEME NT_PRACTICES_FOR_MANGO_PRODU CTION_AND_TRADE/link/5858d81708ae6 4cb3d480bb0/download
9. Rekha Misra, Pallavi Chavan, Radheshyam Verma. Agricultural credit in India in the 2000s: Growth, distribution and linkages with productivity. The J. Appl. Econ. Res. 2018;10(2):169-197.
    Available:https://doi.org/10.1177/09738010 15625378
10. Genesca GE, Grifell TE. Profits and total factor productivity: A comparative analysis. Omega. The Int. J. Management S. 1992;20(5/6):553–568.
    DOI: 10.1016/0305-0483(92)90002-O
11. Bisaliah S. Decomposition analysis of output change under new production technology in wheat farming: Some implications to returns on investment. Indian J. Agric. Econ. 1977;32(3):193-201.
12. Tuong. Economic analysis on production of high quality rice in Cuulong delta, Vietnam, Omon rice. 2010;17:174-178.
13. Swain M, Kalamkar SS, Ojha MK, Sharma S. Agricultural diversification towards horticulture in Rajasthan prospects and challenges. Agric Situ India. 2014;71(3):5-13.
14. Eric Njuki, Boris E. Bravo-Ureta, Christopher J. O'Donnell. A new look at the decomposition of agricultural productivity growth incorporating weather effects. Plos one; 2018.
    Available:https://doi.org/10.1371/journal.po ne.0192432
    https://journals.plos.org/plosone/article?id= 10.1371/journal.pone.0192432
15. Mubbashira Nazir, Saira Batool, Ali Tariq, Abid Hussain. Inter decadal growth variability and decomposition analysis of fruit crops in Punjab. Pakistan J Agri. Res. 2016;29(3).
16. Shadmehri, Mohammad Taher. Estimating growth rates and decomposition analysis of agricultural production in Iran (1970-2000). Trends Agric. Econ. 2008;1(1):14-26.
17. Boubaker Dhehibi, Mohammed Elloumi, Emna Messaoud. Measuring irrigation water use efficiency using stochastic production, frontier: An application on citrus producing farm in Tunisia. Afr J. Agric Rev Econ. 2009;1(2):45-48.