Biological Forum – An International Journal **14(2): 1175-1189(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Factor Productivity and Technical Change in Odisha's Agriculture: A Spatial and Temporal Analysis

Kiran L. Kadam[1*], S.N. Mishra[2], R.K. Mishra[2], B.P. Mohapatra[3] and P.N. Pradhan[4]

[1]Ph.D. Scholar, Department of Agricultural Economics,
College of Agriculture OUAT, Bhubaneswar (Odisha), India.
[2]Professor, Department of Agricultural Economics,
College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[3]Professor, Department of Extension Education,
College of Agriculture OUAT, Bhubaneswar (Odisha), India.
[4]Professor, Department of Agricultural statistics,
College of Agriculture OUAT, Bhubaneswar (Odisha), India.

(Corresponding author: Kiran L. Kadam)*
(Received 29 March 2022, Accepted 30 May, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Agricultural productivity and technological changes are important for enhancing growth in agriculture and measurement of these would help to determine the direction of investments inagriculture. The measure that compares output with the levels of use of inputs would be the most ideal one. Keeping this in view, the total factor productivity (TFP) approach was used to decompose productivity. The TFP was decomposed into its three constituent's *viz*., technical change, scale economies and the residual which in turn was interpreted as a measure of efficiency. The analysis was performed for the state as a whole as well as for the 10 agro-climatic zones The study made use of both cross-section and time series data from 1997-2007 to 2008-2018 and were obtained from the Directorate of Economics and Statistics, planning department and the department of agriculture. The analysis considered major crops and comprised of variables.

The total factor productivity (TFP) in Odisha increased at the rate of 0.05 per cent per annumduring the entire period of study. This trend was due to higher growth of output (0.38 percent) in relation to the growth of input use (0.33 per cent). During the first phase, the TFP declined by 0.02 per cent per annum while in the second phase TFP increased by 0.18 per cent per annum. The variation in TFP among the zones around the trend was mainly due tovariation in output. The growth in agricultural labour force in the state was positive andhigher in the second phase when compared to the first phase Introduction.

Keywords: Total factor productivity (TFP), Technical change and scale economies.

INTRODUCTION

The present situation in Indian agriculture rightly deserves a renewed attention because of two reasons. First, at micro level farmers continue to be vulnerable to monsoon failures and their incomes badly affected. Secondly at the macro level, the fast changing international agricultural trade competition requires agriculture to be more efficient. The slow or stagnant growth in agriculture is considered to be a drag on the overall economic growth. The agricultural sector presently is expected to grow at four per cent in order to achieve the nine per cent growth rate that is targeted for the economy.

The extent of India's regional disparities has been an issue since at least independence, and this concern has been partly motivated by a desire to alleviate poverty. Agriculture remains an important feature of the economic, cultural and political landscape in India demonstrated that the poverty responds more to rural and agricultural economic growth than urban economic growth in developing countries. In the post-green revolution period, particularly in Asia, productivity growth has been sustained through increased input use and, more recently, through more efficient use of inputs India is divided into 29 states on administrative reasons. They were of the view that regional imbalances were likely to widen in the absence of state intervention and narrow with politically necessary interventions, till finally the periphery becomes a beneficiary of the external economies of the core.

However, after 50 years of planned development in India, many backward regions remain backward. Recently both inequalities among states and inequalities among districts or regions within states are growing across many states due to misguided policy (Audirac, 1997; Kurian, 2000). Orissa is one of the poorest states located in eastern India is economic security continues to be predicated upon the agriculture sector, and the situation is not likely to change in the foreseeable future. Even now, agriculture supports 58% of the population, as against about 75% at the time of independence. In the same period, the contribution of agriculture and allied sector to the Gross Domestic Product (GDP) has fallen from 61 to 19%. As of today, India supports 16.8% of world is population on 4.2% of world is water resources and 2.3% of global land. And per caput availability of resources is about 4 to 6 times less as compared to world average. This will decrease further due to increasing demographic pressure and consequent diversion of the land for non-agricultural uses.

Around 51% of India is geographical area is already under cultivation as compared to 11% of the world average. The present cropping intensity of 136% has registered an increase of only 25% since independence. Further, rainfed dry lands constitute 65% of the total net sown area. There is also an unprecedented degradation of land (107 million ha) and groundwater resource, and also fall in the rate of growth of total factor productivity. This deceleration needs to be arrested and agricultural productivity has to be doubled to meet growing demands of the population by 2050. Efficiency-mediated improvement in productivity is the most viable option to raise production.

The country recorded impressive achievements in agriculture during three decades since the onset of green revolution in late sixties. This enabled the country to overcome widespread hunger and starvation; achieve self-sufficiency in food; reduce poverty and bring economic transformation in millions of rural families. The situation, however, started turning adverse for the sector around mid-nineties, with slowdown in growth rate of output, which then resulted in stagnation or even decline in farmer's income leading to agrarian distress, which is spreading and turning more and more serious.

India where about 65.97% of the population lives in rural Agriculture is the mainstay of the State's economy, providing employment to about 65% of the total work force, but it contributed only 22.5% to the net state domestic production in More than 46% of the population lives below the poverty line in rural areas, as against 37% for all India in 2004 Percentage of small farmers (with less than 2 ha of land) is about 57% and landless laborers are about 36% of total households in rural Orissa (Mishra, 2009). In most of the development indicators,

The state is located in the eastern coast of India between 170 49' to 220 34' North Latitude and 810 29' to- 870 29' East Longitude. The state is surrounded by Andhra Pradesh on the South-East, Madhya Pradesh on the West, Bihar in North, West Bengal in North-East and Bay of Bengal in the East. In terms of population the state is 11th biggest state in India and in terms of area holds the 9th rank. Physiographic features of the State

The state is divided into two board regions; the plateau region and the coastal region. The Plateau region comprises 77% of total geographical area of the state whereas, rest 23% of geographical area constitute the coastal region. The state has tropical climate, characterized by high temperature, high humidity, medium to high rainfall and short and mild winters. The south-west monsoon normally sets in Orissa is an agrarian state. Agriculture is the mainstay of State's economy and means for sustenance of rural people. An agriculture, animal husbandry, fishery and forestry sub-sector contribute 17.59 % of the state domestic products as against 14.19% at national level and provides employment, directly or indirectly to 65 % of the Research Setting 85 total work force. Evidently, Agriculture plays a critical role in the economy of the state and the livelihood of majority of its populace.

According to the 2011 Census of India, Odisha has a working population of 17,541,589, among them 61% are main workers and rest are marginal workers. 33.9% of the total working female population are main workers. As of June 2014, Odisha has 10,95,151 people registered in various employment exchanges of the state, of them 10,42,826 reported themselves educated. Odisha had a rural unemployment rate of 8.7% and an urban unemployment rate 5.8% calculated based on the current daily status basis in the 68th National Sample Survey (2011-2012). The per capita income of the state was 98,983 in 2013–14.

Problem statement. Agricultural production has been an issue of concern for some years in India in general and Odisha in particular. Worries about the growth potential of agriculture has emerged since the second half of the 1990s, when the sector suffered a slow down after rapid growth in the initial stage of the Green Revolution. Pessimism continued to develop in the 2000s. As one of the lessons from the recent crises, it is now widely recognized that productivity growth is the key factor in economic development and sustained growth. Most governments are putting emphasis on productivity growth as one of the major goals of economic policy. Many economists conceive that the relative returns to agricultural activities have been too low and investment in agriculture has been insufficient. Theoretically, sources of economic growth are composed of factor accumulation and productivity growth. The first source may lead to high growth rates, but only for a limited period of time. Thereafter, the law of diminishing returns inevitably occurs. Consequently, sustained growth can only be achieved through productivity growth, that is, the ability to produce more and more output with the same amount of input.

In the context, it is important to examine critically the past performance of agriculture and based on it, future prospects of growth can be assessed. Total factor Productivity (TFP) is a ratio of an index of aggregate output to aggregate input. TFP is one of the most convenient indicators to evaluate economic performance as an ex-post facto. Growth of total factor productivity provides society with an opportunity to increase the welfare of people. Therefore, accurate measurement of TFP is crucial for understanding changes in productivity growth. Keeping in view the importance of agriculture in the State economy, quantitative assessment of TFP and contribution of various factors to TFP growth at the State level was undertaken with the following specific objectives. This will help in reorienting of the programmes and priorities of agricultural development so as to achieve higher growth of agriculture for economic prosperity**.** Government provided more incentives such as remunerative prices to protect farmers' interest, availability of credit facilities, improving irrigation facilities, improving markets of both output and input, more investment in agricultural research and extension services, etc. to farmers to produce more. After these developments, it is expected that farmers would become more price responsive. But, the previous studies as well as recent studies have shown that Indian agriculture is low price responsive (Rao, 2005).

In the agricultural production of Odisha some pertinent questions like what is the direction of productivity?, What is the direction and type of technical change?, Are there economies of scale in agricultural production?, Are inputs efficiently utilized? and What are the constraints in achieving higher agricultural productivity? need elaboration. In this study an attempt has been made to understand the above raised issues by developing a system of productivity analysis and its decomposition into meaningful constituents. In addition, constraints for achieving higher productivity in the state have to be identified.

METHODOLOGY

This section discusses in brief about the selection of study area, selection of crops, source and nature of data collected, period of study and theoretical framework of the analytical techniques used.

The details of this chapter are discussed under the following headings: Description of the study area Sampling design Collection of data and Methods of analysis

Description of the study area. The study pertains to the state of Odisha which is located between the latitudes 17.78°N and 22.73°N, and longitudes between 81.37E and 87.53E. The state has an area of 155,707 km^2, which is 4.87% of total area of India, and a coastline of 450 km. Odisha has been divided into 10 agro-climatic zones. The high rainfall areas of hilly and coastal zones record 1300 mm to 4700 mm rainfall. The transitional zones receive medium rain fall ranging between 800 mm and 1300 mm and low rainfall (465 mm to 800 mm) is witnessed in dry zones indicating varied rainfall behavior, cropping patterns and soil types, consequent variations in production and productivity

The study covers the ten "agro-climatic zones' of Odisha which are based on rainfall pattern, topography, soil type and cropping pattern. The details of the districts coming in different agro climatic zones are presented in Table, 1. In defining an agro-climatic zone, block is considered as the administrative unit since the data on climate, land use, crop production, input supply, institutional and infrastructural facilities are not available below that level. It is to be mentioned here that Planning Commission suggested accepting district as unit of planning because of their administrative framework and definite geographical boundaries. At this level a co- ordination between macro and micro level planning can also be established. Therefore, the entire district or if maximum number of blocks of a particular district falls under a specified agro-climatic zone the same is considered as a representative district (Table 1). The data on variables (Table 2) were obtained for the years 1997-2007 to 2008-2018 covering a period of 22 years. For the purpose of dynamic analysis the total period of 22 years was split into two sub-periods as indicated below

Sampling design. For the purpose of analysing the productivity and technical change the state of Odisha was choosen as the primary unit with agro-climatic zones as the sub-units. From each agroclimatic zone one representative district was selected using multistage stratified sampling procedure for detailed analysis. The selected districts are indicated in Table 1.

Collection of Data. For the purpose of analysis, both time series and cross section data were used. The variables or parameters considered in the study are presented in Table 2. The data relating to these selected variables were obtained mainly from published sources as well as unpublished reports of the department of agriculture, directorate of economics and statistics and department of planning, Government of Odisha.

Since large numbers of variables were involved in the analysis and the sources of information were many, there were some gaps with respect to some of the variables like labour and number of tractors. In such cases linear interpolation was resorted to get the missing values. Whenever, data on sample district representing agro climatic zone was not available, figures were apportioned based on consumption of inputs of respective districts.

METHOD OF ANALYSIS

Analysis of total factor productivity (TFP) by Tornqvist-Theil divisia chained index number approach.

Analysis of TFP attempts to measure the amount of increase in total output which is not accounted for by increase in total inputs. TFP index can be defined as the ratio of weighted combination of output to awaited combination of inputs (Rao, 2005). Various methods have been used for analyzing the TFP index (Christensen, 1975). In this study, Tornqvist Theil index was used for computing the total output, total input and TFP indices of selected crops. This Tornqvist Theil index is considered as a superior index for calculating TFP (Rosegrant and Evenson 1995).

This index provides reliable aggregation of inputs and outputs under the assumptions of constant returns to scale, competitive behavior and input- output separability. An added benefit of this index is that it accounts for some changes in quality of inputs also. Because of the use of current factor prices for constructing the weights for input- output index, quality improvements in inputs are built-in to the extent that these are reflected in higher wages and rental rates (Desai, 2012).

The study was carried out in Odisha during 1997-2018. Data relating to selected variables from the publications of Directorate of Economics and Statistics, Odisha. The quantities of inputs used per hectare and their per hectare expenditure, yield and per unit/hectare price of crops output were collected from "Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops", Directorate of Economics and Statistics (DES), GOI. The missing year data on inputs, outputs and their prices were predicted using interpolation and extrapolation based on trends in the available data.

By expressing in logarithmic form the Tornquist-Theil TFP index is given by equation-$\ln(TFP_t / TFP_{t-1}) = ½ \sum_j (R_{jt} + R_{jt-1}) \ln(Q_{jt} / Q_{jt-1}) - ½ \sum_i (C_{it} + C_{it-1}) \ln(X_{it} / X_{it-1})$

Where,

Rjt = Share of output, j in revenues in the year t, Qjt = Output j in the year t, Cit = Share of input, I in total input cost in year t, Xit = Input *i* in period *t*

Qj and Xi are in monetary value

This index was computed as the ratio of an index of aggregate outputs to an index to aggregate inputs of individual crop. Considering the index equal to 100 in a particular year (1997 in the present study) and accumulating the measure based on the above equation results the TFP index. This TFP index was calculated for all crops collectively. For collective estimation of TFP for those crops.

In the study, the input, output and TFP indices were calculated both in current price and constant price (at price of 1997) of the inputs and outputs to find out whether there any price effect was existed or not. Again, the indices were also computed for per hectare area and total area under the selected crops in Odisha to know how efficiently the input was used in both situations.

Table 1: Sample districts for each Agro-climatic zone in Odisha.

Sr. No.	Agro-climatic Zone	Districts	Sampling District	Area of sampling district(km^2)
1.	**North Western Plateau**	Sundargarh, parts of Deogarh, Sambalpur & Jharsuguda	**Sundargarh**	9712
2.	**North Central Plateau**	Mayurbhanj, major parts of Keonjhar, (except Anandapur & Ghasipura block)	**Mayurbhanj**	10,418
3.	**North Eastern Coastal Plain**	Balasore, Bhadrak, parts of Jajpur& hatdihi block of Keonjhar	**Balasore**	3,634
4.	**East & South Eastern Coastal Plain**	Kendrapara, Khurda, Jagatsinghpur, part of Cuttack, Puri, Nayagarh & part of Ganjam	**Puri**	3,051
5.	**North Eastern Ghat**	Phulbani, Rayagada, Gajapati, part of Ganjam & small patches of Koraput	**Rayagada**	7,584
6.	**Eastern Ghat High Land**	Major parts of Koraput, Nabarangpur	**Koraput**	8807
7.	**South Eastern Ghat**	Malkangiri & part of Keonjhar	**Keonjhar**	8204
8.	**Western Undulating Zone**	Kalahandi & Nuapada	**Kalahandi**	7920
9.	**Western Central Table Land**	Bargarh, Bolangir, Boudh, Sonepur, parts of Sambalpur & Jharsuguda	**Bolangir**	6575
10.	**Mid Central Table Land**	Angul, Dhenkanal, parts of Cuttack & Jajpur	**Angul**	6232

Table 2: Variables considered and their code numbers assigned in the study.

Sr. No.	Code	Variable	Sl. No.	Code	Variable
I. Crop outputs			30	X8	Plant protection costs
1.	Y1	Paddy	31	X9	Diesel oil charges
2.	Y2	Maize	32	X10	Depreciation costs
3.	Y3	Bajra	33	X11	Labour value
4.	Y4	Ragi	34	X12	Land rent
5.	Y5	Wheat	**III. Wholesale aggregate Price indices**		
6.	Y6	Miner millets	35	X13	Wage rate in Rupees
7.	Y7	Tur	36	X14	Land rent in Rupees
8.	Y8	Turmeric	37	X15	Seed price
9.	Y9	Bengal gram	38	X16	Fertilizer price index
10.	Y10	Other pulses	39	X17	Energy price index
11.	Y11	Groundnut	40	X18	Capital interest index
12.	Y12	Sesamum	41	X19	All inputs price index
13.	Y13	Sunflower	42	X20	Cereal price index
14.	Y14	Other oilseeds	43	X21	Pulses price index
15.	Y15	Sugarcane	44	X22	Oilseeds price index
16.	Y16	Tobacco	45	X23	Nonfood crops price index
17.	Y17	Cotton	46	X24	Food grains price index
18.	Y18	Rubber	47	X25	Commercial crops price index
19.	Y19	Onion	48	X26	All crops price index
20.	Y20	Garlic	**IV. Agricultural infrastructure**		
21.	Y21	Chillies	49	X27	No. of rural banks
22.	Y22	Potato	50	X28	No. of markets
II. Aggregate input			51	X29	No. of fertilizer outlets
23.	X1	Seed value	52	X30	No. of IP sets energized
24.	X2	Fertilizer value	53	X31	No. of tractors
25.	X3	FYM value	54	X32	No. of rural literate Labour
26.	X4	Rapair and Maintenance cost	55	X33	no. of bovine population
27.	X5	Irrigation charges	56	X34	Irrigated area in ha.
28.	X6	Marketing charges	57	X35	Rural road length in km
29.	X7	Electricity charges	58	X36	No. of rural labour force

To estimate the TFP index for individual crops per hectare, all physical quantities of all the eight inputs used and output produced particular crop were collected for all years and were multiplied with their respective prices to obtain their value terms. Then estimated out total cost per hectare by adding values of all inputs and similarly calculated out total revenue by adding outputs (main product and by product if any) of each individual crops for each year. After that, the contribution of each individual item to its respective total was estimated and considered as its share. In this case all the inputs and outputs were in value terms used per hectare of the individual crops. Again, for estimating the TFP per hectare for all crops collectively, first combined together the outputs produced and all inputs used per hectare of the all crops and then found out their share to total for all years. On the other hand, for calculating the TFP index for the total area under the each selected individual crop in the state, the per hectare expenditure of each input and revenue from each output were multiplied with respective crop area during each year. The expenditures on all inputs and revenue from each output were added to estimate total expenditure and total revenue of the particular crop for each year. Then computed the share of each individual item. By aggregating crop wise expenditure on each input items and revenue from each output, the TFP was calculated for all crops collectively every year.

After, estimating the shares of inputs and outputs, average share of the each inputs as well as each output of two succeeding years, t and t-1 were computed. After that all value of items were converted into logarithm form and then found out the ratio of inputs and outputs at t year to t-1 year. Then multiplied with their respective average shares to find out the individual input and output indices. By adding those individual input and output indices, the composite input and output indices were obtained. Then, the differences between composite output and composite input indices were estimated which in turn provided TFP.

Then to find out the final input, output and TFP indices, took antilog of the composite input, output and TFP and considered the value of all indices for base year 1997 as 100. Then finally, value of all indices for next to base year and so on calculated by multiplying antilog value of index of the same year to final index of previous year.

As mentioned above, all the indices were calculated out both current price and constant price. At first, all the inputs and outputs were valued at price of the respective years and based on those values TFP and other indices were calculated, again, all the inputs and outputs were valued at a constant price of the year of 1997 and based on those indices were estimated. This estimation would give a clear picture about price effect on all the estimated indices.

The estimation of input, output, and TFP growth rates for the specified periods was done by fitting an exponential (or semi-log) trend equation. It was noted that, input, output and TFP growth rates were also estimated by fitting the same exponential (or semi-log) trend equation to the triennium moving average of input, output and TFP indices. It was done to avoid the drastic variation in time series data. The exponential functional form:

$Y = ab^t$ or,

$\ln y = \ln a + t \ln b$

Where,

y = time series data on input, output and TFP b = regression coefficient

t = time period in year

Compound Growth Rate (CGR) input, output and TFP was computed by using the formula: CGR = Antilog (b-1) × 100

To estimate the contribution of TFP in agriculture, its per cent share in total output wasestimated.

RESULT

The results of the study are presented in fourth sections. The first section centers on growth and changing agricultural productivity in Odisha and in the ten agro-climatic zones of the state. The second section is set apart to present the details on assessment of technical change in crop production during the study period. In the third section, the growth performance and technical change are compared between high productive and low productive agro-climatic zones. The fourth section concentrates on identifying the constraints for achieving higher agricultural productivity growth and determinants for TFP in the state.

Growth and changing agricultural productivity in the state. The growth and changing productivity in the 10 agro-climatic zones and the state as a whole were assessed by considering the information on area, production and prices of 16 crops. The value of inputs used (in Rupees) have been obtained for seeds, fertilizers, farm yard manure, maintenance and repair charges of fixed assets, irrigation charges, marketing costs, electricity charges, pesticide costs, diesel oil charges, depreciation, wages in agricultural sector both family and hired labour and land rent. The prices considered were the weighted average of wholesale prices prevailed in the state and for agro-climatic zones, the wholesale prices recorded at the district levels have been used as proxy. The Tornqvist-Theil divisia chained indices were computed to assess the growth and the results are presented in Table 3.

Aggregate growth in output, input and total factor productivity (TFP).

Over the entire period (1997 to 2018) of study the output recorded a growth rate of 10.26 per cent. During the same period, input use index increased by 7.36 per cent. The TFP index decreased in the first period and recorded slight increase in second period. However, for the entire period it recorded a mere 2.70 per cent growth. The growth of TFP at 0.05 per cent per annum is a resultant of output growth at 0.27 per cent minus the input growth at the rate of 0.23 per cent per annum, the pattern of growth in TFP could be divided into two distinct phases. In the first phase, representing the period 1997 to 2007 the TFP declined by 0.02 per cent per annum.

In the second phase representing the period 2008 to 2018 the TFP grew at 0.17 per cent per annum. The growth in output and input indices obviously explain the behavior in TFP growth. In the first phase, the growth in output was marginally lower than the growth in input which resulted in a decline of TFP by 0.02 per cent. In the second phase, the growth of output was higher than the growth in the input. Hence, TFP recorded a growth rate of 0.17 per cent per annum. In the first phase, the decline in TFP was not only due to low output growth but also due to proportionally high increase in the use of inputs. On the contrary, in the second phase output growth was higher with proportionately low input use resulting in the growth of TFP at 0.17 per cent per annum per annum) while during the second phase it grew at the rate of 0.52 per cent per annum. Thus, the aggregate growth of about 0.23 per cent recorded during the entire study period has mainly taken place during the second phase indicating improved efficiency in the use of land over the time period

Aggregate partial productivities of labour and land. The growth rates in the partial productivity indices for labour and land presented in Table 3 indicated that labour productivity decreased significantly in both the periods.

However, land productivity index recorded a positive growth rates in both the periods. The growth rate during the first phase for land productivity was almost stagnant (0.04 per cent Table 3 Tornqvist-Theil Divisia Chained Aggregate Output, Input TFP and PartialProductivity Indices for Odisha State.

Aggregate growth for use of individual inputs. The aggregate indices for individual inputs (Table 4) indicated labour use recording a growth rate of 10.51 per cent, land 2.67 per cent, material inputs 9.37 per cent, energy and capital use in agriculture each at about 08 per cent. The average annual growth for labour, material inputs, energy and capital use in Odisha's agriculture recorded higher growth rates during second phase while in case of land use it was higher during the first phase.

Costs shares and annual growth rates of output and inputs. The average value of cost shares for the period 1997-2018 are presented in Table 5 together with the growth rates of indices for output and individual inputs. The weights for each of the twelve inputs were computed from their shares in total cost. The average share of each of the are presented in Table 5. For arriving at the material input index, four inputs namely seed, fertilizer, farm yard manure and pesticides were considered. The energy index comprised of irrigation, electricity and diesel oil charges. The capital index was constructed using the value of current repairs and maintenance of fixed assets and consumption of fixed capital.

From the Table 5 it is clear that crop output recorded a growth rate of 8.02 per cent during the first phase while it grew at the rate of 09.72 per cent during the second phase. The growth rates for individual inputs depicted in Fig. 5 provide the explanation of the intensification paradox in seed, fertilizer and pesticide use. It is interesting to note that land and labour together accounted for about more than 80 per cent of the input weights. There hasbeen a mixed growth in the use of inputs over the entire period. The weight on land and labour no doubt conceals the love of intensifications. However, it is clear that most of the inputs recorded more than 10 per cent growth per annum. In fact, land, seed and farm yard manure recorded lesser growth rates compared to other inputs. During the first phase, 7 out of 12 inputs recorded a growth rate over 10 per cent. The growth in the usage of pesticides, electricity and fertilizers were quite high.

Table 3.

Year	Output	Input	TFP	Labour Productivity	Land Productivity
1997	100	100	100	100	100
1998	100.05	100.09	99.96	99.84	99.89
1999	100.21	100.18	100.01	99.88	100.13
2000	101.23	100.26	101.94	101.82	102.07
2001	101.57	100.83	100.73	100.61	100.86
2002	102.03	101.12	100.89	100.77	101.02
2003	101.58	101.38	100.19	100.07	100.32
2004	100.87	101.34	99.53	99.41	99.66
2005	103.81	101.82	101.95	101.82	102.07
2006	101.42	101.96	99.47	99.34	99.59
2007	102.08	102.2	99.88	99.76	100.01
2008	102.71	102.26	100.44	100.32	100.57
2009	103.56	102.77	100.76	100.64	100.89
2010	103.03	102.97	100.05	99.92	100.17
2011	104.43	103.4	100.99	100.85	101.1
2012	104.56	104.23	100.31	100.18	100.43
2013	104.24	104.32	99.92	99.8	100.05
2014	105.62	104.88	100.70	100.58	100.83
2015	106.65	105.25	101.33	101.2	101.45
2016	107.99	105.97	101.90	101.72	101.97
2017	108.94	106.98	101.83	101.72	101.97
2018	110.26	107.36	102.70	102.15	102.4

Annual average growth rates (%) by periods 1997-2018

1997-2018	0.34	0.33	0.05	-0.05	0.23
1997-2007	0.27	0.23	-0.03	-0.10	0.04
2008-2018	0.68	0.49	0.18 13	-0.01	0.52

Table 4: Tornqvist-Theil divisia chained indices for individual inputs in Odisha's agriculture

Year	Labour	Land	Material Input	Energy	Capital
1997	100	100	100	100	100
1998	100.23	100.21	100.06	100.44	100.32
1999	100.32	100.42	100.19	100.53	100.41
2000	100.4	100.42	100.4	100.61	100.49
2001	100.97	100.77	100.98	101.18	101.06
2002	101.26	100.98	101.33	101.47	101.35
2003	101.52	101.23	101.41	101.73	101.61
2004	101.48	100.89	101.33	101.69	101.57
2005	101.96	101.55	101.84	102.17	102.05
2006	102.1	101.78	101.75	102.31	102.19
2007	102.34	101.76	101.92	102.55	102.43
2008	102.4	101.63	102.41	102.61	102.49
2009	102.91	102.24	102.9	103.12	103
2010	103.11	102.05	103.43	103.32	103.2
2011	103.54	102.3	104.28	103.75	103.63
2012	104.37	102.49	105.03	104.58	104.46
2013	104.46	102.32	105.33	104.67	104.55
2014	105.02	102.77	106.2	105.23	105.11
2015	105.39	103.06	106.09	105.6	105.48
2016	106.11	102.92	107.9	106.32	106.2
2017	107.12	103.18	108.54	107.33	107.21
2018	107.5	103.18	109.34	108.35	108.23

Annual average growth rates (%) by periods 1997-2018

1997-2018	0.43	0.15	0.41	0.44	0.49
1997-2007	0.32	0.18	0.21	0.33	0.19
2008-2018	0.55	0.14	15 0.65	0.35	0.91

A similar trend was observed during the second phase particularly, the growth in the use of electricity and seed. The growth recorded for land and labour inputs have declined over the study period. Since they together accounted for a major share of total cost, the growth in aggregate input was lower when compared to the aggregate output during the same period.

Comparative analysis of growth in ten agro-climatic zones of the state. The average annual growth rates by period for the ten agro climatic zones in the statewere computed for both outputs and inputs. The results of the same are presented in Table 6. Aggregate growth in output, input and TFP in ten agro climatic zones.

The annual average growth rates of Tornqvist-Theil divisia chained output indices for the entire period (1997-2018) in ten agro-climatic zones of Odisha ranged from 0.30 per cent in western central table land zone to 0.48 per cent in western plateau zone. During the first phase, the least growth rate was noticed in North Eastern Ghats (0.10 per cent) and highest in western undulating zone (0.40 per cent). The growth rate in the second phase was low at 0.33 per cent per annum in the western central table land zone and was high (0.93 per cent per annum) for North Eastern Ghats. Similarly, the growth in input use was least (0.29 per cent) in north western plateau zone and highest (0.36 per cent) in East & South Eastern coastal plain and South Eastern Ghats zone. The growth rate during first phase was least at 0.20 per cent in north western plateau and was highest at 0.32 per cent in western undulating zone. A highest growth rate of 0.57 per cent per annum during second phase was observed in north-eastern coastal zone. In general, the annual growth rate in input indices indicated that there was not much variation between the zones. However, relatively lower growth rates were observed in the first phase when compared to the second phase in most of the zones.

The growth in the total factor productivity (TFP) for the entire period (1997-2018)was minimum (-0.05 per cent) in western central table land zone as well as in the south Eastern Ghats zone While, it was maximum (0.19 per cent) in the northern western plateau zone. During first phase (1997 to 2007), the growth rate was least (-0.17 per cent per annum) in the North Eastern Ghats zone and highest (0.16 per cent per annum) in the western undulating zone. The growth rate during second phase (2008 to 2018) was least at -0.12 per cent in Western Central table land zone and highest in North Central Plateau zone (0.38 per cent per annum). A closer observation of growth in total factor productivity for the entire period (1997 to 2018) and the sub-periods indicated significant variation among the ten agro-climatic zones and the state. The highest productivity (TFP) growth was noticed in the North Central Plateau zone. The growth in TFP was positive in only four of the ten agro-climatic zones during the first phase. However, the growth in TFP during second phase was positive for 9 out of 10 zones. During second phase, only Western Central table land zone recorded a negative growth rate of -0.12 per cent per annum.

Table 5: Costs shares and annual growth rates of output and inputs in Odisha's agriculture.

	Share Per Cent 1997-2018	**Growth Rate 1997-2018**	**Growth Rate 1997-2007**	**Growth Rate 2008-2018**
Output	**100**	**8.02**	**7.38**	**9.72**
Inputs				
Land	35.49	3.01	4.44	2.67
Labour	40.39	11.23	16.05	10.51
Seed	2.63	8.45	5.1	13.12
Fertilizer	4.32	16.31	20.65	11.17
Farm Yard Manure	3.56	2.82	7.22	4.67
Pesticides	4.09	13.58	18.22	11.98
Irrigation	0.15	13.04	38.05	5.9
Electricity	0.79	13.76	20.71	15.32
Diesel Oil	0.46	10.35	14.22	12.11
Recurring and Maintenance (PA)	2.84	14.54	8.32	20.32
Depreciation	4.42	9.7	10.82	9.37
Marketing Costs	0.86	14.84	8.46	15.18

Aggregate partial productivities of labour and land for different zones in the state. The partial productivity indices for land and labour in the ten agro-climatic zones andthe state as a whole are presented in Table 7. As labour and land cost formed about 80 per cent of the total cost in production process, partial productivities were computed only for these two inputs for the entire period (1997-2018) and also for the sub-periods of the study. The average growth rate of labour productivity for the entire period of study was negative in all the agro-climatic zones except North Eastern Coastal Plain and East & South Eastern Coastal Plain zones. Both these zones recorded a growth rate of 0.03 per cent per annum. A lowest growth rate of -0.13 per cent was observed in South Eastern Ghat zone. In the first phase, all the agro-climatic zones and consequently the state as a whole recorded a negative labour productivity except the North Western Plateau and Western Undulating zones. The lowest growth rate during the first phase (-0.22 per cent per annum) was observed in the South Eastern Ghat zone. The growth rate was highest (0.05 per cent per annum) in North Western Plateau zone. During second phase (2008-2018), the labour productivity was lowest (-0.14 per cent per annum) in Western Undulating Zone and Western Central table land zones. The highest growth rate was recorded in the North Eastern Ghat zone. Thus, during the entire period of study positive growth in labour productivity was indicated in only two agro-climatic zones viz., North Eastern Coastal Plain Zone and East & South Eastern Coastal Plain zone. The remaining eight zones and the state as a whole recorded negative growth in labour productivity at varied rates. Further, a comparison of the labour productivity growth rates in first and second periods of the study indicated that only two agro-climatic zones have recorded positive productivity in first phase. While in second phase positive growth rates were observed in five zones. Land is an intangible input and at the same time an important asset in crop production. The indices worked out for productivity of land were positive. It varied from 0.15 per cent per annum for South Eastern Ghat Zone to 0.35 per cent per annum for North Eastern Coastal Plain zone during the whole period of study. The growth rate in land productivity during first period was lowest (-0.10 per cent per annum) in North Eastern Ghat zone and was highest (0.23 per cent per annum) in Western Undulating zone. In the second period, land productivity growth rates were positive for all agro-climatic zones and obviously for the whole state. The lowest growth rate in the second period (0.24 per cent per annum) was recorded for Western Central table land zone. The highest growth rate of 0.80 per cent per annum was observed in North Eastern Ghat zone. Like labour, the productivity of land also improved during the second period. The positive growth rate in land productivity Table 6 Tornqvist – Theil divisia chained aggregate output, input and TFP indices growth for different agro-climatic zones in the state.

Table 6.

Sr. No.	Agro-climaticNo zone	Output			Input			TFP		
		1997-2018	1997-2007	2008-2018	1997-2018	1997-2007	2008-2018	1997-2018	1997-2007	2008-2018
1	North Eastern Coastal Plain	0.45	0.37	0.71	0.34	0.24	0.57	0.11	0.13	0.14
2	North Central Plateau	0.38	0.26	0.64	0.30	0.23	0.43	0.08	0.03	0.21
3	North Western Plateau	0.48	0.22	0.82	0.29	0.20	0.44	0.19	0.02	0.38
4	East & South Eastern CoastalPlain	0.46	0.19	0.80	0.36	0.23	0.55	0.10	-0.04	0.25
5	North Eastern Ghat	0.32	0.10	0.93	0.35	0.27	0.54	-0.03	-0.17	0.39
6	Eastern Ghat HighLand	0.34	0.15	0.16	0.35	0.26	0.52	-0.01	-0.11	0.09
7	South Eastern Ghat	0.31	0.10	0.56	0.36	0.260	0.52	-0.05	-0.16	0.04
8	Western Undulating Zone	0.35	0.40	0.51	0.32	0.32	0.46	0.03	0.16	0.04
9	Western Central Table Land	0.30	0.23	0.33	0.35	0.28	045	-0.05	-0.05	-0.12
10	Mid Central Table Land	0.33	0.16	0.53	0.30	0.26	0.44	0.03	-0.10	0.09
	STATE	0.38	0.21	0.66	0.33	0.23	0.49	0.05	-0.02	0.17

Aggregate individual input indices for ten agro-climatic zones and the state. The Tornqvist-Theil divisia chained input indices recorded positive growth rates for labour in all the ten agro-climatic zones and the state as a whole (Table 8). The growth rates for labour indices were lower in Western Central table land and Mid Central Table Land. It was around the state average (0.43 per cent) in other zones. The growth rates were generally higher during the second phase when compared to the first phase with the highest growth rate at 0.72 per cent per annum in North Central Plateau zone.

The average annual growth rate for land indices was positive in both periods. It was lowest (0.09 per cent per annum) in Western Central table land zone and highest in East & South Eastern Coastal Plain (0.21 per cent per annum) during entire period of study. In the first phase, a leas growth rate of 0.12 per cent per annum was recorded in Mid Central Table Land zone with the highest growth rate of 0.20 per cent per annum in Eastern Ghats High Land, North Central Plateau and North Western Plateau zones. For second phase, a lower growth rate of 0.09 per cent per annum was observed in the Western Central table land zone and a highest growth rate of 0.27 per cent was seen in East & South Easter Coastal Plain zone. The pattern of growth rates of material input indices indicated that they were generally low during the first period when compared to the second. This index was highest in Western Central table land (0.32 per cent) zone during the first period while it was highest (0.75 per cent) in the North Central Plateau zone in the second period. The indices for energy use weregenerally low and varied from 0.23 per cent per annum for Mid Central Table Land and South Eastern Ghat zones to 0.73 per cent in the North Central Plateau zone in the first phase.The indices were higher during the second phase with a value of 2.01 per cent per annum in the North Central Plateau. The indices of capital use followed the same trend as was observed for other inputs with lower values during the first period and higher values in the second period. The overall growth in the indices was 0.49 per cent per annum during the entire period. The capital use indices recorded a highest growth rate at 1.67 per cent per annum in the North Western Plateau zone and lowest at 0.83 per cent per annum in Western Central table land zone during the second phase bullock labour appear to be the main reason for a higher level of capital use index. The observe 9.85 per cent increase in crop output may be attributed to positive and relatively higher growth rates observed in the use of the material input, energy and the capital. On the labour and land use which accounted for more than 80 per cent of the cost recorded a declining trend. This indicated a trend towards substitution of labour and land by mechanical and bio-chemical inputs in Odisha's agriculture. A similar explanation was given by Thirtle and Bottomley (1992) for the growth of agriculture in U.K. The growth rates for indices of material inputs, energy consumption and capital use recorded lower values in the first phase when compared to the second phase. The variation among different zones in the use of the above inputs is related to differential quantum of area under irrigation and rainfall pattern. The growth rates were generally lower in high and medium rainfall areas of Mid Central Table Land and Western Central table land. Whereas, the arid and semi-arid tracts have recorded higher growth rates. The increased consumption of diesel oil and electricity to exploit groundwater, especially in the dry land areas has resulted in the growth of energy consumption in agriculture. The increased growth in capital use may be attributed to the continuous adoption of improved technology. The higher growth rates recorded in the use of material inputs, energy consumption and capital use should be interpreted with caution since it is not only due to higher level of input use in quantity terms but also due to increased prices. This is particularlyso since the prices paid have been taken into consideration in arriving at the value which are further used in the construction of indices. In general, the use of labour, material inputs, energy and capital have recorded high growth rates during the second phase when compared to the first phase. On the contrary, land use registered high rates of growth for the zones and the state as a whole during the first phase than in the second phase. This indicated the intensification of variable inputs vis-a-vis the fixed inputs like land in agriculture. The average annual growth rates for output produced and input used were higher in the second phase when compared to the first phase. Unlike the first phase, output performed better than the input use during the second phase resulting in a positive growth in TFP. However, it has to be mentioned here that aggregate outputs have not changed appreciably from the first phase to second phase. bullock labour appear to be the main reason for a higher level of capital use index. The observed 9.85 per cent increase in crop output may be attributed to positive and relatively higher growth rates observed in the use of the material input, energy and the capital. On the labour and land use which accounted for more than 80 per cent of the cost recorded a declining trend. This indicated a trend towards substitution of labour and land by mechanical and bio-chemical inputs in Odisha's agriculture. A similar explanation was given by Thirtle and Bottomley (1992) for the growth of agriculture in U.K. The growth rates

for indices of material inputs, energy consumption and capital use recorded lower values in the first phase when compared to the second phase. The variation among different zones in the use of the above inputs is related to differential quantum of area under irrigation and rainfall pattern. The growth rates were generally lower in high and medium rainfall areas of Mid Central Table Land and Western Central table land. Whereas, the arid and semi-arid tracts have recorded higher growth rates. The increased consumption of diesel oil and electricity to exploit groundwater, especially in the dry land areas has resulted in the growth of energy consumption in agriculture. The increased growth in capital use may be attributed to the continuous adoption of improved technology. The higher growth rates recorded in the use of material inputs, energy consumption and capital use should be interpreted with caution since it is not only due to higher level of input use in quantity terms but also due to increased prices. This is particularly so since the prices paid have been taken into consideration in arriving at the value which are further used in the construction of indices. In general, the use of labour, material inputs, energy and capital have recorded high growth rates during the second phase when compared to the first phase. On the contrary, land use registered high rates of growth for the zones and the state as a whole during the first phase than in the second phase. This indicated the intensification of variable inputs vis-a-vis the fixed inputs like land in agriculture. The average annual growth rates for output produced and input used were higher in the second phase when compared to the first phase. Unlike the first phase, output performed better than the input use during the second phase resulting in a positive growth in TFP. However, it has to be mentioned here that aggregate outputs have not changed appreciably from the first phase to second phase.

DISCUSSION

Growth and changing agricultural productivity in the state. The index number approach was chosen for the measurement of the growth in productivity. The Tornqvist-Theil divisia chained index was preferred because of its superiority and it Appropriateness for the linear homogeneous translog production function (Diewert, 1976). A further advantage of the Tornqvist-Theil divisia chained index is that it accounts for changes in quality of inputs. Since current factor prices are used in constructing the weights, quality, improvements in inputs can be incorporated to the extent that these are reflected in higher wage and rental rates (Capalbo and Vo 1988). These indices provide consistent aggregation of inputs and outputs under the assumptions of competitive behavior, constant returns to scale, Hick's neutral technical change and input output separability. Further, Caves *et al*. (1982) have shown that Tornqvist-Theil divisia chained indices are superlative under very general production structures, i.e., non- homogeneous and non- constant returns to scale, providing consistent aggregation across a range of production structure (Antle and Capalbo 1988).

Table 7: Tornqvist-Theil divisia chained aggregate labour and land partial productivity indices growth for different agro climatic zones of the state (Percentage).

Sr. No.	Agro-climatic No zone	Labour productivity index			Land productivity index		
		1997-2018	1997-2007	2008-2018	1997-2018	1997-2007	2008-2018
1.	North Eastern CoastalPlain	-0.01	0.05	0.01	0.29	0.14	0.55
2	North Central Plateau	-0.08	-0.05	-0.07	0.23	0.06	0.55
3	North Western Plateau	0.03	-0.09	0.11	0.35	0.05	0.63
4	East & South EasternCoastal Plain	0.03	-0.13	0.16	0.25	0.05	0.53
5	North Eastern Ghat	-0.12	-0.21	0.25	0.21	-0.10	0.80
6	Eastern Ghat HighLand	-0.10	-0.16	-0.06	0.19	-0.05	0.49
7	South Eastern Ghat	-0.13	-0.22	-0.11	0.15	-0.09	0.42
8	Western UndulatingZone	-0.09	0.08	-0.14	0.19	0.21	0.35
9.	Western Central TableLand	-0.07	-0.12	-0.14	0.15	0.02	0.24
10	Mid Central TableLand	-0.05	-0.17	0.05	0.19	0.03	0.33
	State	-0.04	-0.09	-0.01	0.20	0.04	0.51

Table 8: Tornqvist-Theil divisia chained aggregate individual input indices growth for different agro-climatic zones in the state.

Sr. No.	Agro-climatic zone	Labour			Land			Material input			Energy			Capital		
		1997-2018	1997-2007	2008-2018	1997-2018	1997-2007	2008-2018	1997-2018	1997-2007	2008-2018	1997-2018	1997-2007	2008-2018	1997-2018	1997-2007	2008-2018
1.	North Eastern Coastal Plain	0.45	0.32	0.70	0.16	0.20	0.16	0.40	0.19	0.74	0.51	0.40	0.87	0.65	0.18	1.67
2.	North Central Plateau	0.45	0.30	0.75	0.15	0.20	0.10	0.36	0.20	0.74	0.74	0.73	2.01	0.45	0.21	0.86
3.	North Western Plateau	0.44	0.33	0.72	0.14	0.17	0.13	0.59	0.31	0.66	0.59	0.33	1.12	0.49	0.18	0.89
4.	East & South Eastern Coastal Plain	0.43	0.35	0.63	0.21	0.14	0.27	0.44	0.22	0.72	0.46	0.34	0.78	0.54	0.19	1.08
5.	North Eastern Ghat	0.43	0.31	0.67	0.14	0.19	0.13	0.41	0.24	0.72	0.40	0.36	0.77	0.47	0.20	0.92
6.	Eastern Ghat High Land	0.44	0.32	0.68	0.14	0.20	0.13	0.43	0.20	0.68	0.42	0.35	0.69	0.48	0.20	0.89
7.	South Eastern Ghat	0.42	0.33	0.67	0.16	0.16	0.15	0.42	0.27	0.54	0.35	0.37	0.49	0.50	0.17	0.95
8.	Western Undulating Zone	0.41	0.32	0.65	0.15	0.18	0.13	0.40	0.20	0.60	0.50	0.34	0.90	0.49	0.20	0.93
9.	Western Central Table Land	0.36	0.35	0.47	0.09	0.19	0.09	0.54	0.26	0.70	0.46	0.54	0.42	0.44	0.16	0.83
10.	Mid Central Table Land	0.35	0.33	0.46	0.14	0.12	0.18	0.38	0.32	0.59	0.35	0.23	0.52	0.48	0.16	0.93
	State	0.44	0.35	0.67	0.15	0.18	0.14	0.41	0.22	0.65	0.44	0.35	0.78	0.49	0.18	0.91

Growth of output, input and total factor productivity (TFP). The total factor productivity (TFP) in the state declined (-0.03 per cent) during first phase (Table 3) while in the second phase it grew at the rate of 0.18 per cent per annum. The growth in output and input indices must explain this behavioral growth of TFP. In the first phase, the growth in output was marginally lower than the growth in input. However, in the second phase, the growth in output was higher than the growth in input. In the first phase, the decline in TFP was not only due to low growth in output but also due to proportionately increased use of inputs. However, in the second phase, higher output growth (0.68 per cent) relative to lower input growth (0.49 per cent) was responsible for the overall TFP growth at 0.18 per cent per annum. This increasing trend has been observed in the total agricultural production where 22 crops have been aggregated. However, declining productivity in the production of major cereals has been indicated in the Report of the Expert Committee on stagnation of agricultural productivity in Odisha. Thus, it is clear that Odisha's aggregate agricultural productivity has not stagnated even though stagnation is observed in the production of major cereals such as paddy which accounts for about 65 per cent of the total area under cultivation. The increased use of fertilizer and pesticides in crop production has also partly contributed to increased productivity. This trend of measure was used by Thirtle and Bottomley (1992) in measuring the growth in productivity.

The Tornqvist-Theil divisia chained output indices in the ten agro-climatic zones and the state as a whole recorded the lowest growth at 0.30 per cent per annum in the Western Central table land with a highest growth at 0.48 per cent in the North Eastern Coastal Plain for the entire period of study. An examination of input indices indicated the existence of minimal variation between the zones. However, it is interesting to note that lower growth rates were observed in the first phase when compared to the second phase.

The average annual growth rate in TFP for the entire period was minimum (-0.05 per cent) in the South Eastern Ghat as well as in Western Central table land, while it was maximum (0.19 per cent) for North western plateau. The TFP growth indicated considerable variation across the ten agro-climatic zones and also between two sub-periods. The growth in TFP was observed to be positive in 4 zones during the first phase while 9 out of 10 zones recorded a positive growth during second phase. The large variation observed in TFP may be attributed to output changes and high fluctuations observed due to weather aberrations. Besides, the varied levels of input use had its own influence on the TFP. The comparative analysis indicated lower rates in output, input use and TFP in the first phase when compared to the second phase. This implied limited impact of the green-revolution in Odisha's agriculture during the first phase. However, the higher levels achieved in the second phase may be attributed to the use of bio-chemical technology in crop production

Growth in labour, land and partial productivity indices. The labour use index increased from 0.32 per cent in the first phase to 0.55 per cent during the second phase. The growth of population particularly the labour force has been high, whereas, employment opportunities have been few. This has resulted in employing large number ofunskilled labour force in the agricultural sector and has been reflected by higher growth rates especially in the second phase all throughout the state. The labour use index recorded a positive growth rate during the study period with comparatively low growth rates during first phase and higher rates in the second phase for different zones. From these results, it could be inferred that labour use increased over the period less than proportionately to crop production in most of the zones except the hilly and coastal zones. The Western Central table land and Mid Central Table Land are endowed with better resources and have different cropping pattern with relatively large area under plantation crops which demand higher level of labour force. Contrary to labour use indices (Table 3) the partial productivity of labour in the state as a whole recorded negative growth rates during first phase as well as the second phase. Positive productivity rates were observed only in two zones during the first phase while it was positive in five zones during the second phase indicating an improvement in labour productivity over time. The negative growth in labour productivity in the agricultural sector of the state may be attributed to the low level of capital formation in agriculture. Labour use in the state has increased at a relativelyhigher pace when compared to land use. Further, the growth in the use of material inputs, energy and capital are not that high to absorb the additional labour force in agriculture. Resultantly, all these factors have contributed to negative productivity of labour. However, the improvement in productivity of labour through decline in negative values in the second phase when compared to first phase suggests that some measures to improve the productivity of labour have yielded positive results. There are some more options to increase its productivity through improvement.

in land quality by watershed management, modernizing irrigation, increasing area under HYV and increasing capital formation in agriculture (Acharya 1992).

The land use index recorded a low growth rate of 0.15 per cent per annum which is quite obvious keeping in view the limited availability of land for further cultivation. The small increase in area appeared to be by way of bringing under cultivation more of marginal and sub- marginal land. The trend in the growth rates of land use indices in the different agro-climatic zones and the state as a whole declined over the study period except in the central dry and coastal zones. These two zones recorded higher growth rates in the second phase as compared to the first phase which is contrary to the one observed in other eight zones. Land productivity index recorded a positive growth rate (0.23 per cent) during the study period. Land productivity during the first phase was almost stagnant (0.04 per cent). However, it increased marginally (0.55 per cent) during the second phase implying that farmers have made efforts to improve the productivity of land through various measures such as soil and water conservation management. However, the land productivity indices have shown positive growth rates for all the zones during the entire period. In general, the land productivity indices were higher in the second phase when compared to the first phase indicating a trend towardsefficient use of land in crop production.

The declining growth rate in land use index is understandably true because of limited scope for area expansion under crops. From this kind of results, it could be inferred that technology change has generated productivity growth, even if it is not substantial by reduced input level and by promoting output growth (Thirtle, 1992). Further, it clearly shows that production cannot be area led in future but has to be productivity led through the increased cropping intensity.

Growth rates in other input use indices. The use of material inputs recorded a growth rate of 0.65 per cent per annum during the second phase. The increased use of material inputs may be attributed to increased area under irrigation which recorded a growth rate of 4.79 per cent per annum. The pattern in the use of energy as measured in terms of an index was high (0.79 per cent) during the second phase mainly due to the growth in number of irrigation pump sets energized and increased purchase of tractors and diesel engines. A steep rise in fuel and electricity charges has also contributed to the growth in the index since all the items in arriving at the index are considered in value terms. The capital use index recorded a higher rate of growth (0.91 per cent per annum) when compared to material input use index. A high rate of replacement of agricultural machinery, equipments, buildings and bullock labour appear to be the main reason for a higher level of capital use index. The observed 9.85 per cent increase in crop output may be attributed to positive and relatively higher growth rates observed in the use of the material input, energy and the capital. On the labour and land use which accounted for more than 80 per cent of the cost recorded a declining trend. This indicateda trend towards substitution of labour and land by mechanical and bio-chemical inputs in Odisha's agriculture. A similar explanation was given by Thirtle and Bottomley (1992) for the growth of agriculture in U.K. The growth rates for indices of material inputs, energy consumption and capital use recorded lower values in the first phase when compared to the second phase. The variation among different zones in the use of the above inputs is related to differential quantum of area under irrigation and rainfall pattern. The growth rates were generally lower in high and medium rainfall areas of Mid Central Table Land and Western Central table land. Whereas, the arid and semi-arid tracts have recorded higher growth rates. The increased consumption of diesel oil and electricity to exploit groundwater, especially in the dry land areas has resulted in the growth of energy consumption in agriculture. The increased growth in capital use may be attributed to the continuous adoption of improved technology. The higher growth rates recorded in the use of material inputs, energy consumption and capital use should be interpreted with caution since it is not only due to higher level of input use in quantity terms but also due to increased prices. This is particularly so since the prices paid have been taken into consideration in arriving at the value which are further used in the construction of indices. In general, the use of labour, material inputs, energy and capital have recorded high growth rates during the second phase when compared to the first phase. On the contrary, land use registered high rates of growth for the zones and the state as a whole during the first phase than in the second phase. This indicated the intensification of variable inputs *vis-a-vis* the fixed inputs like land in agriculture. The average annual growth rates for output produced and input used were higher in the second phase when compared to the first phase. Unlike the first phase, output performed better than the input use during the second phase resulting in a positive growth inTFP. However, it has to be mentioned here that aggregate outputs have not changed appreciably from the first phase to second phase.

SUMMARY AND CONCLUSION

Agricultural productivity and technological changes are important for enhancing growth in agriculture and measurement of these would help to determine the direction of investments in agriculture. The measure that compares output with the levels of use of inputs would be the most ideal one. Keeping this in view, the total factor productivity (TFP) approach was used to decompose productivity. The TFP was decomposed into its three constituent's *viz*., technical change, scale economies and the residual which in turn was interpreted as a measure of efficiency. The technical change was estimated using the translog cost function. The analysis was performed for the state as a whole as well as for the 10 agro-climatic zones and comparisons were made between high and lowproductive zones. The constraints for achieving higher productivity were identified so as to suggest suitable policy options that could be adopted to achieve higher productivity. The study made use of both cross-section and time series data from 1997-2007 to 2008-2018 and were obtained from the Directorate of Economics and Statistics, planning department and the department of agriculture. The analysis considered 22 crops and comprised of 58 variables such as area, production, prices, seeds, fertilizers, farm yard manure, maintenance and repair charges of fixed assets, irrigation charges, marketing costs, electricity, pesticides, diesel oil, depreciation, land rent and labour costs. The Tornqvist-Theil divisia chained indices for TFP for crop production in agro climatic zones and the state as a whole.

The total factor productivity (TFP) in Odisha increased at the rate of 0.05 per cent per annum during the entire period of study. This trend was due to higher growth of output (0.38 per cent) in relation to the growth of input use (0.33 per cent). During the first phase, the TFP declined by 0.02 per cent per annum while in the second phase TFP increased by 0.18 per cent per annum. The variation in TFP among the zones around the trend was mainly due to variation in output. The growth in agricultural labour force in the state was positive and higher in the second phase when compared to the first phase. The labour use index recorded a positive growth rate during the study- period with lower growth rates during first phase when compared to the second phase in most of the zones. The partial productivity for labour in the zones recorded negative growth rates for eight zones in the first phase and five zones in the second phase indicatingan improvement in labour productivity over time. The land use index recorded a low growth indicating limited availability of land for cultivation in the state. The trend in the growth rate of land use indices in different zones and state as a whole declined from the first phase to the second phase. The marginal increase in area appears to be by way of bringing marginal and sub marginal lands under cultivation or through increase in cropping intensity. The land productivity index recorded positive growth rates in all the agro-climatic zones. The land productivity indices were higher in the second phase when compared to the first phase indicating a trend towards efficient use of land in crop production. The individual input indices recorded positive growth rates during the study period. The growth rates for input use were higher in the second phase when compared to the first phase in all the zones. The increased material input consumption is attributed to increased area under irrigation and higher cropping intensity. The increased use of energy in agriculture is attributed to growth in irrigation pump sets, purchase of tractors and diesel engines and also due to steep rise in fuel prices. The growth in capital consumption was attributed to machinery equipments, buildings and bullock labour. The increased input use in agriculture implied intensification of technology in crop production. The technical change registered a positive growth indicating increased use of new technologies in crop production. The technical change was observed to be both labour and input saving.

As the labour productivity indicated a declining trend it was suggested that a part of labour could be diverted to other enterprises so as to achieve higher level of output. Input saving technical change observed in Odisha implied that with lower levels of input use the existing output can be achieved. Thus, higher level of outputs could be achieved with a small increase in the inputs. The dis-economies of scale recorded were attributed to the decline in the size of holding and emphasized the fact that the farmers were operating beyond optimum point on the expansion path. The decomposition of TFP indicated the productivity gains at 0.02 per cent, technical change at 0.07 per cent, scale economies at -0.04 per cent and the residual or efficiency at 0.02 per cent per annum respectively for the entire period of study. This analysis provides evidence that positive effect of technical change and efficiency was neutralized by negative effect of scale economies thereby resulting in lower productivity. This calls for reducing Investment in inputs which are used above the required level to produce a unit of output or bring about optimal combination of inputs to improve the productivity. The decomposition analysis further indicated positive growth in technical change for plain and plateau zones and negative rates in hilly and coastal zones. The operation of positive scale economies was observed in most of the zones. The residual productivity or efficiency was negative in most of the zones implying inefficiency in production. The need to educate the farmers regarding the efficient use of resources in the zones through the extension agencies was felt necessary.

REFERENCES

Acharya, S. (1992). Labour use in Indian agriculture: Analysis at macro level. *Indian journal of Agricultural Economics, 47*(2): 167-184.

Antle, J. M. and Capalbo, S. M. (1988). An introduction to recent developments in production theory and productivity measurement and explanations.

Audirac, N. (1977). Decomposition analysis of output change under new production technology in wheat farming; some implications to return on research investment. *Indian Journal of Agricultural Economics, 32*(4): 193-201.

Capalbo, S. and Vo, T. (1988). A review of evidence on agricultural productivity and aggregate technology. 134-138.

Capalbo, S. M. and Antle, J. M. (1998) Agricultural productivity measurement and explanations. Resources for the future. *Economics, 43*(3): 381-401.

Caves, D. W., Christenson, L. R. and Diewert, W. E. (1982). Multilateral comparisons of output, input and productivity using superlative index numbers. *Economic Journal, 92*: 73-86.

Christensen, L. R. (1975). "Concepts and measurement of agricultural productivity. *American Journal of Agricultural Economics, 57*(5): 910-915.

Coelli, J., Timothy, D. S., Prasada, Rao, Christopher, J O'Donnell and George, E. (2005). An Introduction to Productivity and Efficiency Analysis, Second Edition, Springer: USA.

Desai, G. M. (2012). Issues and themes in growth of fertilizer use in India: an agenda for further research and future policies. *Journal of the Indian Society of. Agricultural statistics, 43*(l): 81-102.

Evenson, R. E. and Pray, C. E. (1991). Research and productivity in Asian agriculture. Cornell University Press: Ithaca and London.

Evenson, R. E., Pray, C. E. and Rosegrant (1999). Agricultural research and productivity growth in India. Research report: 109, International Food Policy Research Institute: Washington, USA.

J. M. Alston, G. W., Norton and Pardey, P. G. (1995).. Science under scarcity: principles and practice for agricultural research evaluation and priority setting. Cornell University Press: Ithaca, London.

Kumar, P. and Mittal, S. (2006). Agricultural Productivity trends in India: Sustainability. *Agril. Econ. Res. Rev. 19*: 71-88.

Kumar, Praduman, S., Mittal and Hossain, M. (2008) Agricultural Growth Accounting and Total Factor Productivity in South Asia: A Review and 21 Policy Implications. *Agricultural Economics Research Review, 21*(2): 145-72.

Rosegrant, M. W. and Evenson, R. E. (1992). Agricultural productivity and sources of growth in South Asia. *American Journal of Agricultural Economics, 74*(3), 757-761.

Mishra, Kumar, P., Kumar, A. and Mittal, S. (2009). Total Factor Productivity of Crop Sector in the Indo-Gangetic Plain of India: Sustainability Issues revisited. *Indian Econ. Rev., 39*(1): 169-201.

Ramesh, Chand., Praduman, K. and Sant Kumar (2011). Total factor productivity and contribution of research investment to agricultural growth in India. Policy paper 25, National Centre for Agricultural Economics and Policy Research. Pusa: New Delhi, India.

Ranjitha, P. and Mruthyunjaya (2015). Total factor productivity in Indian agriculture: Impact of research. Post-Green Revolution Evidence from India, National Centre for Agricultural Economics and Policy Research New Delhi, and International Crops Research Institute for the Semi-Arid Tropics. 2005; 17-24.

Rao, N. C. (2005). Total Factor Productivity in Andhra Pradesh Agriculture. *Agril. Econ. Res. Rev., 18*(1): 1-19.

Thirtle, C., & Bottomley, P. (1992). Total factor productivity in UK agriculture, 1967-90. *Journal of Agricultural Economics*, *43*(3), 381-400.

How to cite this article: Kiran L. Kadam, S.N. Mishra, R.K. Mishra, B.P. Mohapatra and P.N. Pradhan (2022). Factor Productivity and Technical Change in Odisha's Agriculture: A Spatial and temporal analysis**.** *Biological Forum – An International Journal*, *14*(2): 1175-1189.