The Pharma Innovation Journal 2023; SP-12(12): 1582-1589

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(12): 1582-1589

www.thepharmajournal.com
Received: 06-09-2023
Accepted: 11-10-2023

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Estimation of growth and instability in shrimp production of Andhra Pradesh and India

M Rajani, A Balasubramanian and O Sudhakar

Abstract
The growth and instability in terms of area, production and productivity of shrimp in Andhra Pradesh and India were appraised for a period of 16 years from 2005-06 to 2020-21 grouping the data into four sub-periods viz., I (2005-06 to 2008-09), II (2009-10 to 2012-13), III (2013-14 to 2016-17) and IV (2017-18 to 2020-21). The overall compound growth rate of area and production of shrimp in Andhra Pradesh and India were found to be significantly negative (p<0.05) while productivity was positively significant during 2005-06 to 2020-21. In Andhra Pradesh, the maximum growth in production was observed during the sub-period III (17.74%) followed by sub period IV (14.44%). The highest productivity was observed in sub period II (13.53) followed by sub period III (12.37%) whereas the highest growth in area was observed in sub period IV (5.73%) followed by III (5.37%). In India, the highest growth in area (16.41%), production (75.09%) and productivity (62.27%) was observed in sub period IV followed by sub period II. Cuddy-Della Valle instability index provided the best estimates and high instability was found in productivity both in India (218.51%) as well as Andhra Pradesh (47.33%) whereas the low instability was noticed in production and area of culture. The overall low instability index for area and production for Andhra Pradesh did not vary much while they varied greatly for India. The relationship between area and production of shrimp culture was significantly correlated over the period for Andhra Pradesh (99.26%) and India (65.04%).

Keywords: Aquaculture, shrimp, trend, growth, instability index

Introduction
Shrimp culture in India has an extensive history of successes and challenges reflecting both the potential and problems in the development of shrimp industry. The industry initially grew rapidly during the 1990s, largely through the efforts of individual farmers, but operated in an environment where there was often a lack of adequate regulatory guidance. During this time the total area occupied by farms being engaged for shrimp aquaculture increased dramatically, however over 85% of farms were of small size i.e., less than 2 hectare. These small farms could able to produce the shrimp to a tune of 0.73 tons per hectare which was very low compared to other shrimp producing countries. In 2003, a major shift in the Indian shrimp industry took place through introduction of another candidate species *Litopenaeus vannamei* for aquaculture. By the end of the year 2017, the area under culture had increased 50%, production had increased by almost 83% which led the India to the position of second highest shrimp producer in the world (Mahesh *et al.*, 2020; Srinivas *et al.*, 2019) [11, 19]. However, due to various biological, environmental and natural calamities, instability in the shrimp production becomes common in the industry.

Instability acts as one of the important decision parameters in development dynamics and it becomes common phenomena in both agricultural as well as aquaculture production sector. The consequence of the instability in the production output not only cause price fluctuation but also results in wide variations in the disposable income of the farmers. Aquaculture production depends on various physical, environmental and biological parameters which are subjected into significant variations over time like agriculture. The instability in the production sector is calculated using various methods like Coefficient of Variation (CV), Cuddy Della Valle Index (CDVI) and Coppock's instability index (CII), Generally, the year-wise production data is grouped into various sub-periods for compare the instability in different time period for particular crop or animal production (Samarpitha *et al.*, 2013; Krishan *et al.*, 2014; Dudhat *et al.*, 2017; Shabana *et al.*, 2018) [16, 10, 6, 17]. Cuddy-Della Valle index provides the best estimates and instability was found to be more in productivity (4.04%).

Kalpana (2018) [9] studied the time series data on area, production and productivity of jute in India and concluded that jute production in the country was growing with a compound growth rate of 1.30 percent per annum. The growth and instability of the Indian fish and fishery products export and its performance over the past five decades from 1960 to 2013 were estimated by Radhakrishnan *et al.* (2018) [14]. In aquaculture production sector, the estimation of instability in fish or shrimp is undertaken seldom unlike agricultural produces where the instability is calculated for every crop. In India, the state of Andhra Pradesh is largest producer of fish and shrimp in the country and it accounts for about 70 percent of country's shrimp production. Shrimp and fish farming are extensively taken up in the districts of East and West Godavari, Krishna, Prakasam, Nellore and to some extent in Guntur.

The state has massive development in fisheries and aquaculture sector since 1970 despite it experiences often profound fluctuation in aquaculture production due to various reasons like diseases, natural calamities, climate change and social issues etc. In this context, this study was carried out to appraise the growth and instability occurred in the area, production and productivity of shrimp culture in Andhra Pradesh for the period of last 16 years from 2005-06 to 2020-21.

Materials and Methods

Data on shrimp production for the state of Andhra Pradesh and India were collected from the publications of Annual Reports in Marine Products Export Development Authority (MPEDA), Govt of India for a period of 16 years (2005-06 to 2020-21). The whole data period i.e. from 2005-06 to 2020-2021 was divided into four sub periods consisting of four years per period viz., I period (2005-06 to 2008-09), II period (2009-10 to 2012-13), III period (2013-14 to 2016-17) and IV period (2017-18 to 2020-21). The assessment was designed utilizing the data pertaining to the area of shrimp culture in hectare (ha), production in million tonnes and productivity in Million Ton/ha/year to weigh up the growth performance, instability index and degree of relationship instability between area, production and productivity of shrimp production obtained from the state of Andhra Pradesh and India. For weighing up the above parameters, various statistical measures like mean, correlation coefficient and coefficient of variations were worked out.

Estimation of Compound Growth Rates

Growth rates are worked out to examine the tendency of variable to increase, decrease or remain stagnant over a period of time. It also indicates the magnitude of the rate of change in the variable under consideration per unit of time. For the present study, Compound growth trend was used to estimate the growth in area, production and productivity of shrimp in Andhra Pradesh and India. The trend analysis for the four sub divided data pertaining to the area, production and productivity of shrimp for the state of Andhra Pradesh and India were carried out using linear Compound Annual Growth Rate (CAGR) and they were estimated using the following exponential function

$y = a\, b^t$ ---------- (1)

where 'y' is a dependent variable for which growth rate is to be calculated, 't' is an independent variable which is represented as time variable, a, b are the parameters of the exponential model. Taking logarithms on both sides of the model (1), it becomes

Log y= log a + t log b and it can be written in linear model as Y=A + Bt, where Y= Log y, A= log a, B= log b, t = t

From the approximated function, the compound growth rate was worked out and estimated in the following function model;

CAGR (r) = [Antilog (log b) -1]*100 where 'r' is compound growth rate.

Instability Analysis in Area, Production and Productivity

Instability expounds that deviation from the "trend". In aquaculture, instability is an inherent characteristic due to weather conditions, seasonal variation in area and production of crops from year to year. The aquaculture instability can be measured by various means. In the present study, the instability analysis in the area, production and productivity of shrimp for the state of Andhra Pradesh and India were premeditated using three measures of instability viz., Coefficient of Variation (CV), Cuddy-Della Valle Index (CDVI) and Coppock Instability Index (CII). The present study contemplates mainly on Cuddy Della Valle Index for measuring the instability ignoring the CV even though it is the simplest measure of instability, as it over-estimates the level of instability in time series production data which are characterized by long-term trends. However, the estimation of CV is essential for calculating CDVI.

Coefficient of Variation

The coefficient of variation was used as measure to study the variability in area, production and productivity of shrimp. The coefficient of variation or index of instability was computed by using the following method

Coefficient of Variation (CV) = $\frac{\sigma}{\overline{X}} \times 100$, where, σ = Standard Deviation, $\overline{X}$ = Mean

Cuddy - Della Valle Instability Index

The Cuddy Della Valle Index de-trends the annual price and shows the exact direction of the instability. Hence, it is a better measure to capture instability in aquaculture production. A low value of this index indicates low instability in Aqua Production and vice-versa. CDVI was originally developed by Cuddy and Della Valle (1978) [5] for measuring the instability in time series data that is characterized by trend. The estimable form of the function is as follows:

Cuddy-Della Valle Instability Index (CDVI) = $C.V \times \sqrt{1 - \overline{R}^2}$

Where, C.V is the simple Coefficient of Variation in percent, $\overline{R}^2$ is the coefficient of determination from time trend regression adjusted by the number of degree of freedom. The ranges of CDV Index (Rakesh, 2014; Kalidas, *et al.*, 2020; Vekariya, *et al.*, 2020) [15, 8, 21] are given as follows

- Low instability = between 0 and 15
- Medium instability = greater than 15 and lower than 30
- High instability = greater than 30

Coppock Instability Index

Instability in shrimp production of Andhra Pradesh and India were also analyzed using Coppock Instability Index (CII) which is calculated as the antilog of the square root of the logarithmic variance using the following function (Coppock, 1962) [4]. CII was used by many researchers to examine the instability in time series production data of various produces (Wasim, 2007; Fauzi and Anna, 2012; Radhakrishnan *et al.* 2016 & 2018) [22, 13, 14] have used CII to examine instability.

Coppock Instability Index (CII) = $Anti\log(\sqrt{V\log}-1)\times 100$

where $V\log = \frac{\sum\left(\log\frac{X_{t+1}}{X_t} - m\right)^2}{n}$ 'Xt' is Area / Production / Productivity, 't' is number of years 'm' is mean of the difference between logs of X_{t+1}, X_t and Log V is logarithmic variance of the series

Coppock instability index is a close approximation of the average year to year percentage variation adjusted for trend and the advantage is that it measures the instability in relation to the trend in Production. A higher numerical value for the index represents greater instability like CDVI.

Results and Discussion

Trend analysis in the area, production and productivity of shrimp in Andhra Pradesh and India for a period of sixteen years from 2005-06 to 2020-21was studied using compound annual growth rate.

Trend analysis of Area, Production and Productivity of shrimp in Andhra Pradesh

The constructed indices of area, production and productivity of shrimp for the state of Andhra Pradesh are given in Fig. 1 and Fig. 2, It is evident from the illustration that, decreasing trend was observed under the area of shrimp culture and it fluctuated widely within the period of 16 years in the state Andhra Pradesh. The maximum change in area was observed in the year 2013-14 over the 16 years followed by 2005-06, 2009-10 and 2012-13, respectively. The maximum decline in the area of culture was observed in the year 2019-2020 over the last 16 years. In case of production, maximum increasing trend was observed in the year 2006-07 followed by 2010-11 and 2011-12 respectively. Maximum decline in the shrimp production in the Andhra Pradesh was observed in the year 2019-2020. Overall trends observed in the area of shrimp culture and productions of Andhra Pradesh were abruptly irregular.

The shrimp production as well as the area of culture got declined from the year 2006-07 to 2008-09 and afterwards the production rose till 2011-12 though the area of culture was in declining trend from 2011-12 onwards till 2020-21. The decline in production and area was due to continuous viral diseases and heavy mortality occurred in the culture of tiger shrimp Penaeus monodon and later sudden increase in production from the year 2009-10 was due to introduction of new candidate species white shrimp *Penaeus vannamei* in aquaculture practices and expansion of culture in freshwater or low saline waters (Ashok *et al.*, 2015) [3].

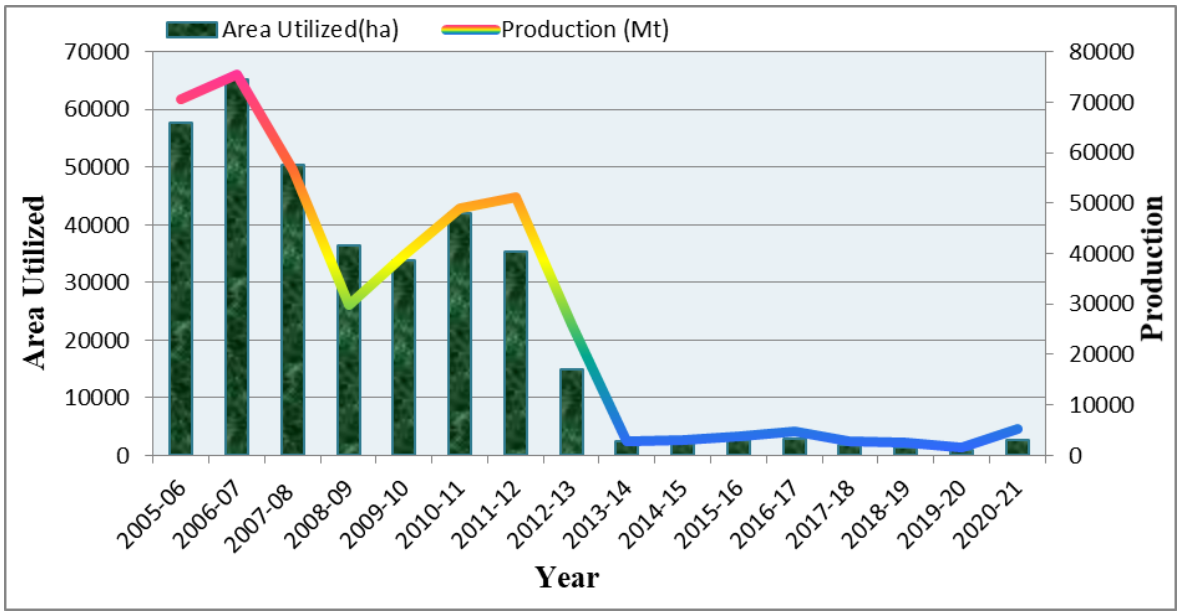

Fig 1: Area and Production of Shrimp in Andhra Pradesh Over the period from 2005-06 to 2020-21

Farmed shrimp productions from the Northern districts of Andhra Pradesh viz., Srikakulam to East Godavari declined by 16% and the state received the lowest production in the year 2020 among the entire period of studies. The declined production and its consequent financial losses were due to panic harvests during the early stages of lockdown and subsequent disruptions. The region performed better in production in the last six months of 2020 compared to the first half of the year and the last six months of 2019 (Anon, 2020) [1].

The shrimp production again started declining from 2012-13 onwards due to diversion of many shrimp farmers into fish culture and agriculture practices due to heavy losses faced by them in yesteryears. Besides, the Andhra Pradesh is always succumbed to extreme weather conditions and natural calamities like cyclones floods etc., and they might have

pulled down the shrimp production in these periods (Udayasekhar, 2012) [20]. However, the production was almost uniform from 2013-14 to 2021 and it might be due to the adoptability of the farmers to the new candidate species for continuing their culture practices and improvement in their technical efficiency in culture practices (Sivaraman *et al.*, 2015) [18].

In case of shrimp productivity, maximum increasing trend was observed in the year 2020-21 followed by 2018-19 and 2012-13 respectively. The productivity observed throughout the analysis period is above 1 MT/Ha/Y except 2008-09. Maximum decline in the productivity observed in the state of Andhra Pradesh in the year 2008-09 might be due to shift of farming practices from Tiger shrimp to Pacific white shrimp and lack of technique know- how of the farmers about the new candidate species.

Trend analysis of Area, Production and Productivity of shrimp in India: The indices of area and production of the country are presented in Fig. 2 and Fig. 3. It could be observed evidently from the illustration that, the area of shrimp culture and production trailed crisscross fashion from 2005-06 to 2020-21. Nevertheless, the huge area of culture (1,49,632 ha) and production (1,44,347 MT) could be seen in the year 2006-07 over the period of 16 years followed by 2005-06, 2007-08 and 2011-12 in the case of area and 2005-06 and 2011-12 in the case of production. In contrary, the maximum decline in the area (48,653) could be seen in the year 2019-2020 whereas the lowest production (35,437 MT) obtained was in the year 2020-21 over the 16 years of study.

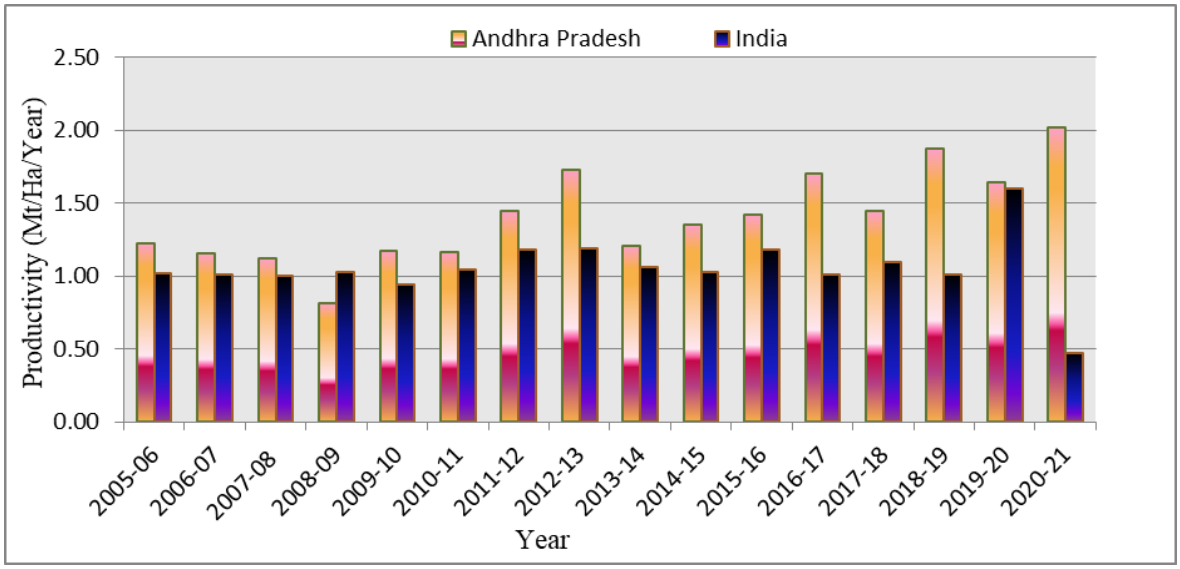

Fig 2: Productivity of Shrimp in Andhra Pradesh and India over the period from 2005-06 to 2020-21

In case of productivity, maximum increasing trend was observed in 2019-20 (1.6 MT) followed by 2012-13 (1.19 MT) and 2015-16 (1.18 MT) respectively while maximum decline was observed in the year 2020-21 (0.47MT). The productivity was above 1 MT/Ha/Y almost in entire study period except 2009-10 (0.94 MT) and 2020-21(0.47MT). The trend appeared in productivity also resembled the production and area. Unlike the production, the productivity in the country did not vary much instead maintained almost uniformity which might be due to technical efficiency of the farmers who accustomed to the alternative species *P. vannamei* and adoptability of better farm management practices in shrimp culture.

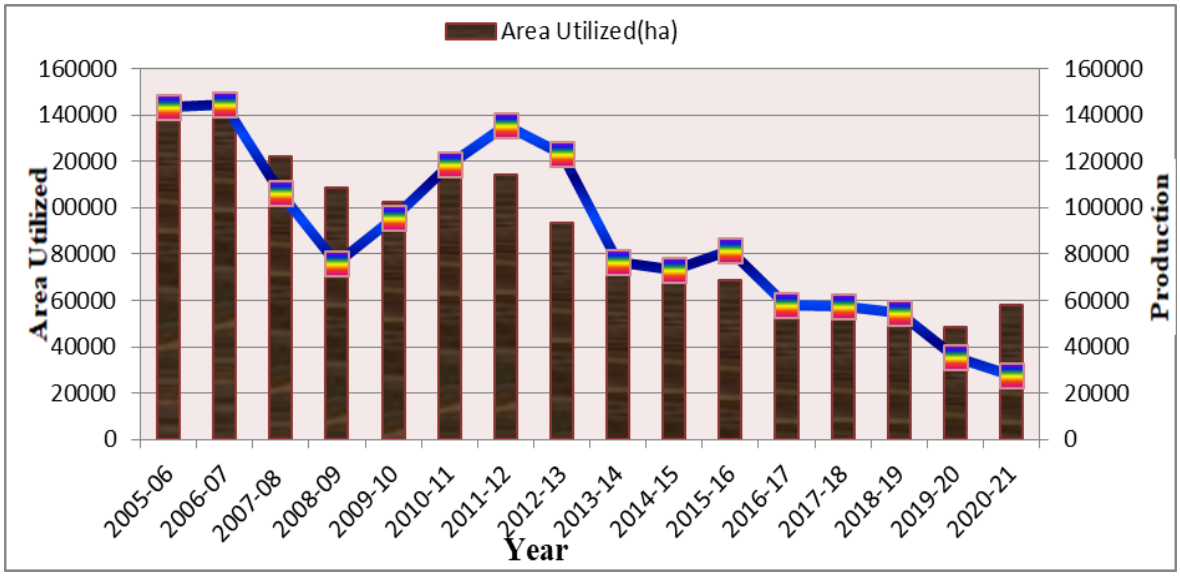

Fig 3: Area and Production of Shrimp in India Over the period from 2005-06 to 2020-21

However, the fluctuation in the area and production was common phenomena throughout the study period and it might be due to various production constraints like non availability of good quality seed, high cost of feed, poor transfer of advanced techniques, viral diseases, poor quality of chemicals, natural disaster, poor marketing, continuous failure of crop, marketing constraints, price fluctuation in international market, threat of antidumping and ban imposed from countries like USA (Patil and Arpita, 2020) [12].

Shrimp production in India for 2020 had declined by 19% from a record production of nearly 800,000 tonnes in 2019 to about 650,000 tonnes. Apart from the continuing production challenges other than the disease problems, the Covid-19 pandemic and related lockdown contributed quite significantly to the decline of shrimp production in the country (Anon, 2020) [1].

Estimation of Compound Annual Growth Rate in Area, Production and Productivity of Shrimp in Andhra Pradesh and India

The compound growth rate equation was approximated to assess the growth in the area, production, and productivity of shrimp in Andhra Pradesh and India for a period of 16 years (2005-06 to 2020 -2021) which were divided in four sub-periods. The data analysed using linear compound annual growth rate formula are given in Table. 1 and Fig. 4 & Fig. 5.

In India, the total area under shrimp cultivation during the year 2005-2006 was 1, 40,682 hectare and decreased to 1, 08,526 hectare in 2020-21. The overall (2005-06 to 2020-21) compound annual growth rate of area of shrimp was found to be negative (-5.91) and significant decline ($p<0.05$) in the area at the rate of 30.56% per year. Similarly, the production of shrimp was also found to be negative (-1.41) and there was no significant increase in the production instead the significant ($p<0.05$) decline was found at the rate of 1.41% per year. However, the productivity was found to be positive (5.47) and significant increase ($p<0.05$) was found at the rate of 5.47% per year (Table.1).

In India, the positive growth in productivity was obtained in the sub-Period I (0.21%), II (8.28%) and IV (62.27%) without any significant ($p>0.05$) increase whereas negative growth was observed in the sub-period III. In the case of production, the positive growth of 8.87% was obtained in sub period II without any significant increase ($p>0.05$) while negative growth was observed in sub period I and III. In area of shrimp culture also exhibited negative growth in all the periods except sub period IV (Table 1). The increase of productivity in the sub period IV could be due to stability observed in the Pacific white shrimp culture practices and expansion of culture in the fresh water bodies. The negative growth in the production in the sub period I and III might be due to poor technical knowledge and sudden viral and fungal disease outbreak.

Table 1: Growth rates of area, production and productivity of shrimp in Andhra Pradesh and India

Periods	Area		Production		Productivity	
	AP	India	AP	India	AP	India
I (2005-06 to 2008-09)	-16.41	-9.75	-28.88	-22.07	11.57	0.21
II (2009-10 to 2012-13)	-26.05	-2.59	-12.22	8.87	13.53	8.28
III (2013-14 to 2016-17)	5.37	-6.49	17.74*	-7.26	12.37*	-0.80
IV (2017-18 to 2020-21)	5.73	16.41	14.44	75.09	8.71	62.27
Overall period (2005-06 to 2020-21)	-30.99*	-5.91*	-27.19*	-1.41	30.8*	5.47*
* level of significant p < 0.05						

In Andhra Pradesh, compound annual growth rates of area and production of shrimp were found to be negative (-30.99 and -27.19) and significant decline ($p<0.05$) was observed in the area and production at the rate of 30.99% and 27.19% per year respectively. The growth of productivity was found to be positive (30.8) and significant increase ($p<0.05$) could be noticed in the productivity at the rate of 30.8% per year.

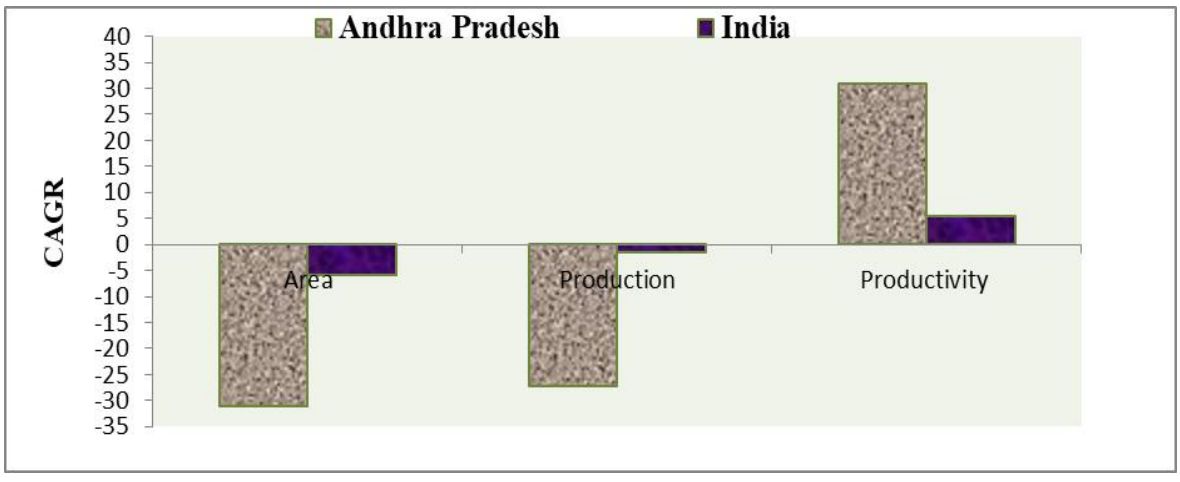

Fig 4: Compound Annual Growth Rates of Area, Production and Productivity of Shrimp in Andhra Pradesh and India over the period from 2005-06 to 2020-21

In Andhra Pradesh, the highest growth in production, productivity and area was observed in the III sub-period (2013-14 to 2016-17), sub-period II (2009-10 to 2012-13) and sub-period IV (2017-18 to 2020-21) respectively. During these periods, the highest CAGR obtained in production, productivity and area were 17.74%, 13.53% and 5.73%

respectively. Nonetheless, in India, the highest growth in area, production and productivity was observed only in IV sub-period (2017-18 to 2020-21) unlike Andhra Pradesh. During this period, the highest compound annual growth rate in production, productivity and area were 75.09%, 62.27% and (16.41%) respectively.

In Andhra Pradesh, the positive productivity growth was observed in all four sub periods and obtained significant (p<0.05) growth only at sub period III. In the case of production and area of shrimp culture, the positive growth was obtained in periods III and IV while negative growth was seen in the first two periods. It could be seen with significant increase (p<0.05) in the production during the sub period III (Table 1).

The increasing trend of CAGR in production from the state of Andhra Pradesh during sub period III 2013-14 to 2016-17 might be due to standardization of culture technique of alternative species vannamei and increase of culture area though the productivity was low during these periods due to outbreak of viral diseases compared to high CAGR obtained during sub period II 2009-10 to 2012-13.

The increase of CAGR in shrimp productivity during sub period II 2009-10 to 2012-13 could be achieved since the culture of newly introduced alternative species *P. vannamei* did not face much technical as well as health problems during culture. Likewise, the declined area of shrimp culture started increasing gradually during the sub period IV (2017-18 to 2020-21) due to the stability in the culture practices, seed availability, expansion of farming in inland region and improvement in the know-how's in farming practices.

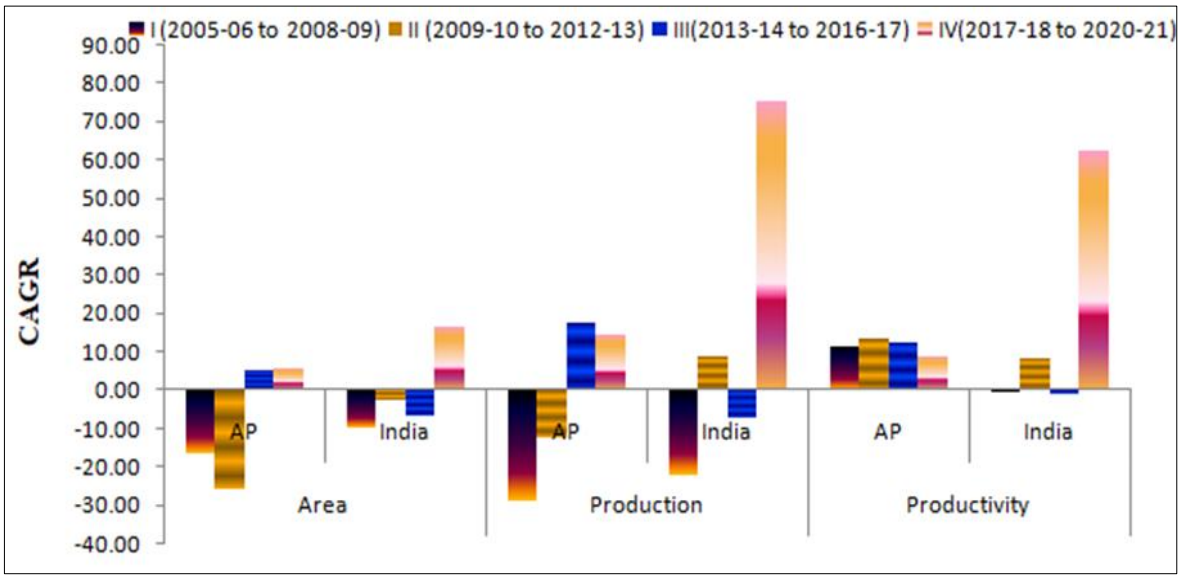

Fig 5: CAGR of Area, Production and Productivity of Shrimp in Andhra Pradesh and India over period wise

Instability Analysis of Area, Production and Productivity of Shrimp in Andhra Pradesh and India

Cuddy-Della Valle Index (CDVI) is considered as best measure in determining the instability in the production sector as it has apparent scale of measure. Hence, in this study also CDVI was chosen for estimating inter annual fluctuation in area, production and productivity of shrimp in India and Andhra Pradesh. It is well known that fluctuation in area and production are interrelated, if other factor remains constant then the increment in area of culture yields higher production but variation may be observed in productivity since it relies on various factors like weather conditions, technological changes, etc. However, the changes in the production may also be occurred due to endogenous and exogenous factors other than the area utilization.

The coefficient of variation and Cuddy-Della Valle Index in area, production and productivity of shrimp for India and Andhra Pradesh are presented in Table 2 and Fig.6.

Table 2: Instability in area, production and productivity of shrimp in Andhra Pradesh and India

Time Period	CV			CDVI			CII		
	Area	Production	Productivity	Area	Production	Productivity	Area	Production	Productivity
	Andhra Pradesh								
Period-I	2.32	3.9	85.17	1.53	1.86	78.18	47.31	56.29	46.10
Period-II	4.46	2.93	61.55	3.72	1.73	24.83	58.21	50.17	44.45
Period-III	1.39	2.93	49.61	1.31	3.09	12.35	41.02	46.74	43.31
Period-IV	6.34	6.67	26.84	7.67	2.38	21.2	58.58	62.28	42.62
Overall Period	17.6	15.54	73.37	6.78	7.42	47.33	181.71	158.26	46.38
	India								
Period-I	1.22	2.61	78.03	0.71	1.11	93	42.46	49.86	37.23
Period-II	0.83	1.25	143.3	0.95	0.95	56.07	40.48	42.57	41.19
Period-III	0.52	1.32	127.54	0.3	1.25	145.77	40.44	42.63	39.72
Period-IV	3.16	12.45	144.17	3.08	11.21	90.04	40.37	52.45	61.5
Overall Period	3.08	6.01	247.43	1.9	6.19	218.51	52.75	59.95	46.90

In India, high CDVI (218.51%) was obtained in productivity in over all period and it indicates that high instability was prevalent during overall study period from 2005-06 to 2020-21. However, low CDVI was obtained for both production (6.19) and area (1.90) of culture for the data of entire study period and it divulges the low instability in production and area (Table 2).

In Andhra Pradesh, as a whole the Cuddy-Della Valle instability index provides best estimates and instability was found to be high in productivity (47.33) and low in both production (7.42) and area (6.78). The stability in area and production in shrimp culture in both India and Andhra Pradesh implies that shrimp culture hold a significant portion in culture pattern.

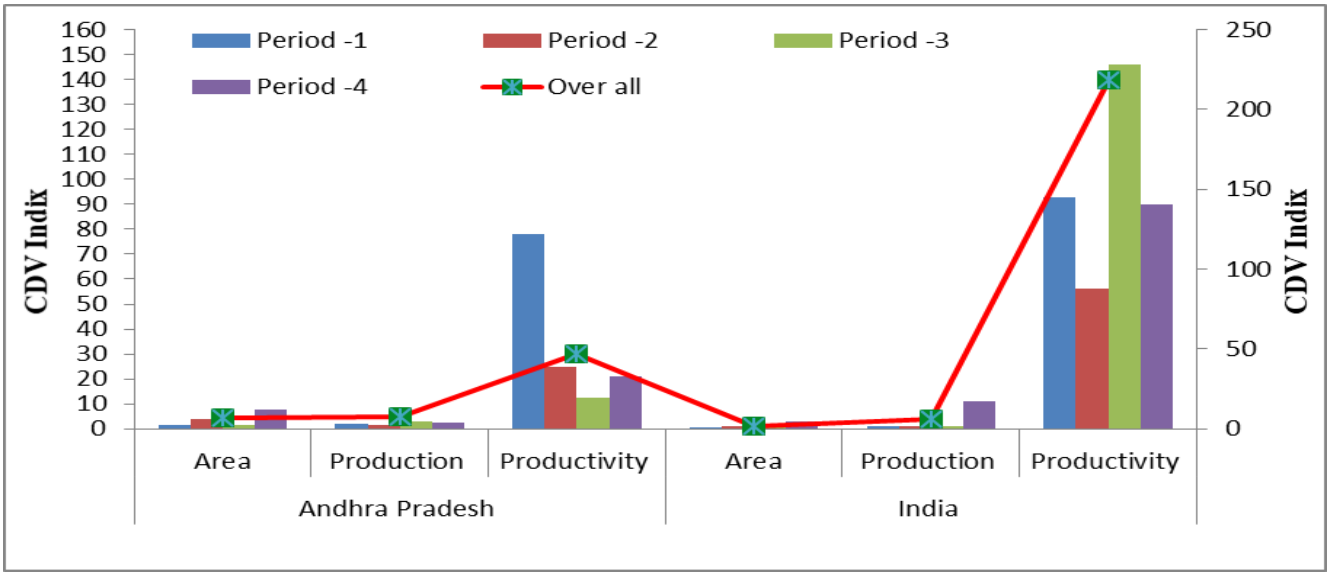

Fig 6: CDV Index of Area, Production and Productivity of Shrimp in Andhra Pradesh and India over the period 2005-06 to 2020-21

In India, the productivity of all four sub periods was found to be highly instable and the highest instability was observed in the Sub-Period III (145.77%). In the case production and area of culture, all sub-periods demonstrated low instability which indicates that there were no much changes in the culture area and production as well. It might be attributed to adequate availability of required inputs for farming activities.

In Andhra Pradesh, the high instability in productivity (78.18%) was perceived at Sub-Period I (2005-06 to 2008-09) while medium instability was observed during sub period II and IV and low instability at sub period III. Alike India, the low instability was found in production and area of culture in all four sub periods of entire period of study (Table 2). It could be interpreted that the variability in production would be the compound result of fluctuation in productivity and area.

Correlation between area and production of shrimp in Andhra Pradesh and India

The degree of relationship between area and production of shrimp culture was measured by correlation test. In India**,** it was observed that correlation coefficient of area and production of shrimp over the period i.e. 2005-06 to 2020-21 is 65.04% which is moderate positive and highly significant. It implies that the production in shrimp culture is reasonable influenced by increment in area. However, in Andhra Pradesh, high significant correlation (99.26%) between the area and shrimp production was found in the entire study period. It revealed that the production of shrimp culture is highly influenced with increment of area.

Conclusion

In the present study, the Growth and the Instability in shrimp farming were appraised utilizing time series data available for Andhra Pradesh and India for the period of 16 years from 2005-06 to 2020-2021. The trend analysis revealed that there were several fluctuations in the growth pattern of area, production and productivity of shrimp in entire Andhra Pradesh and India. Further, the analysis emphasized that growth in area and production was in declining trend though productivity was in promising trend in the entire study period. The decline in the production and area might have occurred due to endogenous and exogenous factors like, natural calamities, weather, technical deficiency, disease problems etc. The CDV instability index for Andhra Pradesh and India for the overall period of study revealed high inter-annual fluctuation in shrimp productivity and indicated high instability compared to production and area of shrimp culture. It is interpreted that the variability in production is the compound result of fluctuation in productivity and area. High instability in productivity might have occurred due to irregular availability of inputs like, quality seed, feed, chemicals, technology, etc for the farming activities. As the shrimp production relies on increment of area of culture, it is necessary to take up productivity enhancing measures in shrimp culture to sustain the shrimp production.

Acknowledgments

The authors thank to an anonymous reviewer and the journal editor for their helpful and valuable comments.

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