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Study of Chemical Fertilizers Consumption in India: Comparative and Forecasting Approach

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Authors Contribution

Shiv Kumar Singh Pundhir : Data analysis and manuscript prepration;

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Abstract

The chemical fertilizers are used to increase crop yield. The excessive use of chemical fertilizers damages soil, air and water quality which is fatal for human health. In this work, a mathematical model is developed to forecast fertilizer consumption in India. Historical data for the period of 2001 to 2021 is analyzed to find trend patterns by using a scatter diagram and a mathematical model is developed by using the method of least square. The forecast accuracy of the model is verified using Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE) concepts. Fertilizer consumption in the top five states regarding daily used crops and fruit production is also analyzed. Fertilizer consumption in India is also compared with the USA, China, Brazil and Australia.

Keywords : Fertilizers, Forecasting, Least square method, Trend equation, Forecast accuracy

In the past fertilizers were developed naturally in villages which were beneficial for land and the environment. To increase crop production farmers used chemical fertilizers. Chemical fertilizers contain mainly three nutrients Nitrogen, Phosphorus and Potassium. This extensive worldwide use of fertilizers causes serious environmental problems like ozone depletion, soil health problems and water, soil and air pollution. As per statistics due to the increasing world population, 40-60 per cent of crops are grown with the help of fertilizers and pesticides. The sad part is that almost 50 per cent or more of the population is feeding these crops. Fertilizers will support soil to grow plants but excessive use of fertilizers damages the fertility of the soil by increasing acids in the soil. The use of these fertilizers also harms water balance on the earth. Phosphates and nitrates available in fertilizers when mixed with lake or river water are destroying the lives of animals living on earth and in the water. Many birds and animals lose their life due to these nitrates and phosphates. Also when this water is used by humans, it causes many incurable diseases. A lot of research have been done, which proves that excessive use of fertilizer is too dangerous for the environment, soil, water, air and human health. Patra *et al.* (2016) observed that improper utilization of fertilizers is the cause of the environmental problem. Kumari *et al.* (2014) studied the adverse effects of fertilizers and pesticides on humans and found that long-term use of these crops will cause health problems. They recommended eco-friendly fertilizers to increase crop production. Miah *et al.* (2014) studied the effect of fertilizers on the health of farmers in Bangladesh. Nicolopoulou *et al.* (2016) studied on impact of chemical pesticides on human health. Getahun and Keefer (2016) studied that fertilizers cause degradation of groundwater quality. Vinothkanna *et al.* (2020) studied the impact of fertilizers on soil quality degradation. Sharma and Singhvi (2017) studied the effect of pesticides and

fertilizers on human health. Choudhary *et al.* (2014) studied the adverse effect of pesticides on farmers' health. Kumar *et al.* (2013) studied to know the impact of pesticides on the environment and health of farmers. Thuy (2015) studied the impact of Dichloro-diphenyl-trichloroethane (DDT) on human health. He found that due to long residual efficacy and accumulation through the food chain, it badly affects human health. Yargholi and Azarneshan (2014) studied that the long-term effect of chemical fertilizers highly affects the soil. Pahalvi *et al.* ((2021) found that excessive fertilizer consumption damage the soil, water and air quality. Srivastav (2020) found that pesticides and chemical fertilizers damage water and soil quality. Ramalingam *et al.* (2022) studied the impact of nitrate-containing water on human health in South India. They found that nitrate is the most significant issue in human health. Tyagi *et al.* (2022) found that excessive use of chemical fertilizers increases crop yield but also damages environmental sustainability. Chemical fertilizers degrade soil, water, and the quality of produced foods. Devi *et al.* (2022) found that chemical fertilizer consumption is increased in developing countries to get more yield. Chemical fertilizers are used unscientifically and sometimes banned chemicals were used which causes serious ecosystem damage. Tripathi *et al.* (2020) found that chemical fertilizers enhance greenhouse gas emissions and decrease soil quality. Wang and Lu (2020) found that China increased N-fertilizers consumption to increase crops of maize, wheat and rice which causes fatal to human health. Dhankhar and Kumar (2023) examined the impact of chemical fertilizers and pesticides on human health. Srivastav *et al.* (2024) found that consumption of NPK fertilizers has increased worldwide, due to which people are drinking nitrate-containing polluted water which causes severe health issues. They suggested to create awareness among farmers for the use of organic fertilizers. Alam *et al.* (2024) studied the water pollution due to chemical fertilizers consumption in Bangladesh. They found that fertilizer consumption highly contributed to water pollution in Bangladesh. Cha *et al.* (2024) suggested to use organic fertilizers to control environmental pollution and toxicity in the soil and water due to chemical fertilizers.

Before globalization, countries like India had large agricultural land to produce sufficient food crops to support their population. However, after globalization and the exponential growth of the real estate market, a big part of agricultural land was acquired by real estate companies and industries. To fulfill the demand, farmers rapidly increased the use of fertilizers to grow more crops. India's population is also increasing rapidly, to feed the people of India, farmers have to yield more crops in the limited agricultural land using chemical fertilizers and pesticides.

In this work, the researchers investigated yearly fertilizers consumption and developed a forecast model using the method of least square to predict fertilizers consumption in India. The trend of consumption of fertilizers in India's top five states regarding the production of daily used crops and fruits is also studied.

Material and Methods

Forecast Model : In this section, forecast model is developed to predict fertilizers consumption in India. Data for the period from 2001 to 2021 is analyzed to develop the model. The forecast model is developed using the method of least square.

Table 1

Yearly consumption of NPK fertilizers (kg/hectare) in India

Year	Fertilizers (kg/hectare)	Year	Fertilizers (kg/hectare)
2001	86.7	2013	130.8
2002	91.5	2014	118.5
2003	86.1	2015	127.5
2004	88.2	2016	130.7
2005	94.5	2017	124.4
2006	104.5	2018	127.9
2007	112.3	2019	133.1
2008	115.3	2020	127.8
2009	127.2	2021	137.2
2010	135.3		
2011	146.3		
2012	142.3		

Source : https://www.rbi.org.in

To examine the trend pattern of fertilizers consumption in India, a scatter diagram is plotted. From Fig. 1, we can see that fertilizers consumption in India follows a positive linear trend.

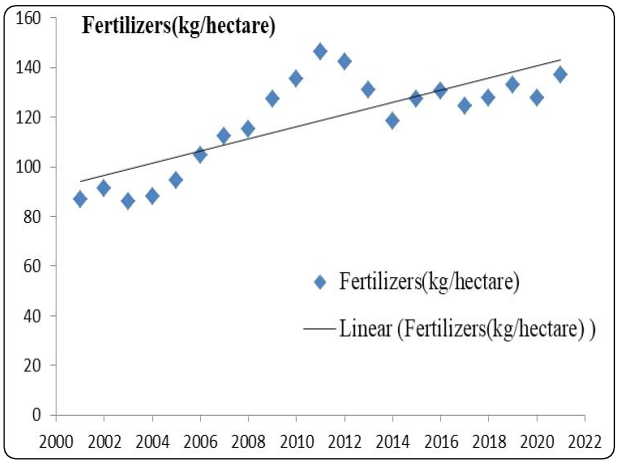

Fig. 1 : Scatter diagram of consumption of fertilizers in India

The trend equation according to the method of least square will be will be $y_e = a+bx$.

To find a and b two normal equations will be solved.

$\sum y = na + b\sum x$ .....(1)

$\sum xy = a\sum x + b\sum x^2$ .....(2)

Where y is the actual consumption of fertilizers and y_e represent the expected consumption of fertilizers (kg/hectare). For each year a year code x is provide. For the base year 2001, year code will be one and for the others year code will be the distance of that year from the base year. So the corresponding x can be found by the formula, year code (x) = current year-base year.

In Table 2 data is shown to develop the linear trend equation, $y_e = a + bx$ using the method of least square.

The trend equation will be $y_e = a + bx$ with the base year 2001.

To find a and b two normal equations given below are developed by putting the corresponding data in Table 2.

TABLE 2

Table for the method of Least Square

Year	Fertilizers (kg/hectare)	X	xy	x^2
2001	86.7	1	86.7	1
2002	91.5	2	183	4
2003	86.1	3	258.3	9
2004	88.2	4	352.8	16
2005	94.5	5	472.5	25
2006	104.5	6	627	36
2007	112.3	7	786.1	49
2008	115.3	8	922.4	64
2009	127.2	9	1144.8	81
2010	135.3	10	1353	100
2011	146.3	11	1609.3	121
2012	142.3	12	1707.6	144
2013	130.8	13	1700.4	169
2014	118.5	14	1659	196
2015	127.5	15	1912.5	225
2016	130.7	16	2091.2	256
2017	124.4	17	2114.8	289
2018	127.9	18	2302.2	324
2019	133.1	19	2528.9	361
2020	127.8	20	2555.8	400
2021	137.2	21	2880.15	441
	$\sum y$=2488	$\sum x$=231	$\sum xy$=29248.45	$\sum x^2$=3311

$\sum y = na + b\sum x$ .....(3)

$\sum xy = a\sum x + b\sum x^2$ .....(4)

So equation (3) and (4) can be written as

$2488 = 21a + 231b$ .....(3)

$29248.45 = 231a + 3311b$ .....(4)

Solving the above equations we found a and b. So value of a is 91.61 and values of b is 2.44.

The trend equation of fertilizers consumption in India will be $y_e = 91.61 + 2.44x$. with the base year 2001.

Forecast Accuracy : In this section, accuracy of the forecast model is verified with the help of Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error(MAPE).

Notations used are shown below

y : Actual fertilizers consumption (kg/hectare)

y_e : Expected or forecasted fertilizers consumption (kg/hectare) as per trend equation. This can be obtained by putting corresponding values of x in the equation $y_e = 91.61 + 2.44x$.

Deviation = Actual value - Forecast value

MAD : Mean absolute deviation = Average of the total absolute deviations

$$MAD = \frac{\sum (\text{Actual value - Forecast value})}{n}$$

MAPE is defined by

$$MAPE = \frac{1}{n}\left(\sum \frac{|\text{Actual-Forecast}|}{\text{Actual}} x100\right)$$

$$\text{Forecast error in percentage} = \frac{|\text{Actual-Forecast}|}{\text{Actual}} x100$$

Results and Discussion

MAD is a measurement of forecast accuracy in quantities. From the above Table 3, MAD from the year 2013-2021 is less than one. From the above Table 3, the MAPE is less than 10 percentages, so we can say that the forecast model is having a good forecast accuracy. Expected fertilizers consumption for the year 2030 and 2040 can be obtained by putting values of x=30 and x=40 in equation y_e =91.61+2.44x. So expected fertilizers consumption for the year 2030 and 2040 will be 164.81 kg/hectare and 384.41 kg/hectare respectively.

Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, and West Bengal states produce daily consumable crops. We can see from the figures shown below that in each state fertilizers consumption follows a positive linear trend. Only in Madhya Pradesh average fertilizer consumption is below 100 kg/ hectare. In Uttar

Table 3

Study of forecast accuracy

Year	Actual fertilizers	Expected fertilizers	Abs deviation	MAD	MAPE	Percentage error
2001	86.7	94.05	7.35	7.35	8.48	8.48
2002	91.5	96.49	4.99	2.50	6.97	5.45
2003	86.1	98.93	12.83	4.28	9.61	14.90
2004	88.2	101.37	13.17	3.29	10.94	14.93
2005	94.5	103.81	9.31	1.86	10.72	9.85
2006	104.5	106.25	1.75	0.29	9.22	1.67
2007	112.3	108.69	3.61	0.52	8.36	3.21
2008	115.3	111.13	4.17	0.52	7.77	3.62
2009	127.2	113.57	13.63	1.51	8.09	10.72
2010	135.3	116.01	19.29	1.93	8.71	14.26
2011	146.3	118.45	27.85	2.53	9.65	19.04
2012	142.3	120.89	21.41	1.78	10.10	15.05
2013	130.8	123.33	7.47	0.57	9.76	5.71
2014	118.5	125.77	7.27	0.52	9.50	6.14
2015	127.5	128.21	0.71	0.05	8.91	0.56
2016	130.7	130.65	0.05	0.00	8.35	0.04
2017	124.4	133.09	8.69	0.51	8.27	6.99
2018	127.9	135.53	7.63	0.42	8.14	5.97
2019	133.1	137.97	4.87	0.26	7.91	3.66
2020	127.79	140.41	12.62	0.63	8.01	9.88
2021	137.15	142.85	5.7	0.27	7.82	4.16

Pradesh, Haryana, Punjab and West Bengal fertilizers consumption is above 150 kg/hectare. In 1990, consumption was 80 kg/hectare and it doubled in Uttar Pradesh and West Bengal. In Punjab and Haryana, it is more than 200 kg/hectare. Maharashtra, Tamil Nadu, Andhra Pradesh, Jammu and Kashmir and Uttar Pradesh are the states that produce a large number of fruits in India. In Jammu and Kashmir, fertilizers use is below 100 kg/hectare, while in other states it is above 100 kg/hectare. In Andhra Pradesh and Tamil Nadu fertilizers consumption is more than 200 kg/hectare.

Graphical Representation of the use of Fertilizers for the Top Five States in Terms of Daily used Crops Production : In this section, data is graphically represented for the five states which are Uttar Pradesh, Haryana, Punjab, Madhya Pradesh and West Bengal, which produce the measure part of daily consumable crops in India.

In Fig. 2 to Fig. 6, fertilizer consumption pattern of five states that produce daily consumable items like wheat, rice and pulses are shown. Wheat and rice are mostly produced in Uttar Pradesh, Haryana and Punjab. In Haryana and Punjab, fertilizer consumption is more than 200 kg/hectare while in Uttar Pradesh it is 170 kg/hectare. West Bengal is a big producer of rice, where fertilizer consumption also shows a linear increasing growth. Mostly pulses are produced in

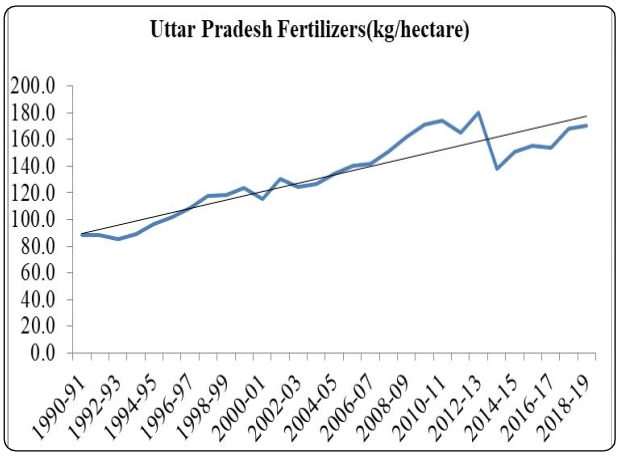

Fig. 2 : Consumption of fertilizers (kg/hectare) in Uttar Pradesh

Source : https://www.rbi.org.in/ScriptspublicationsView.aspx?id=20070

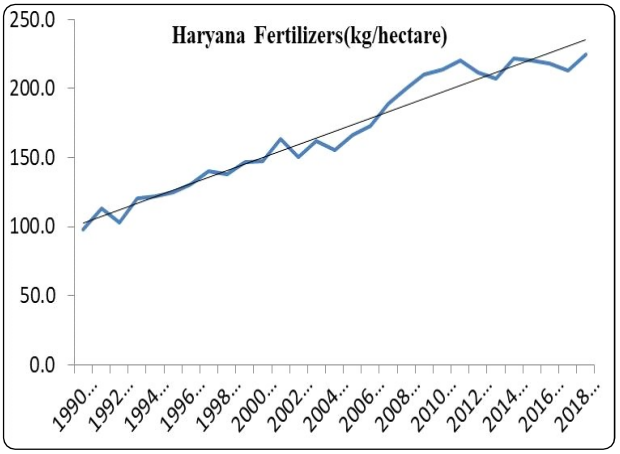

Fig. 3 : Consumption of fertilizers (kg/hectare) in Haryana

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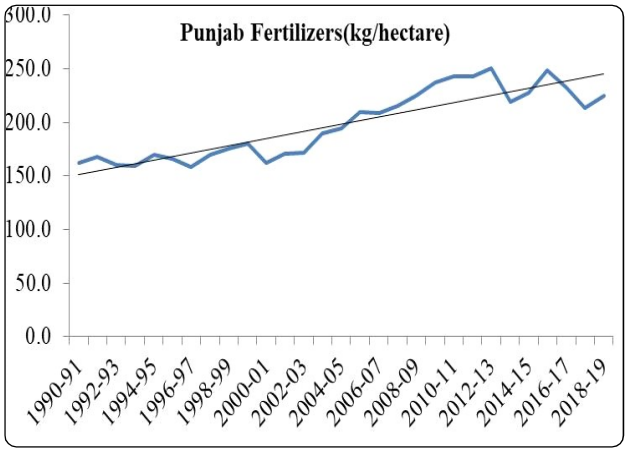

Fig. 4 : Consumption of fertilizers (kg/hectare) in Punjab

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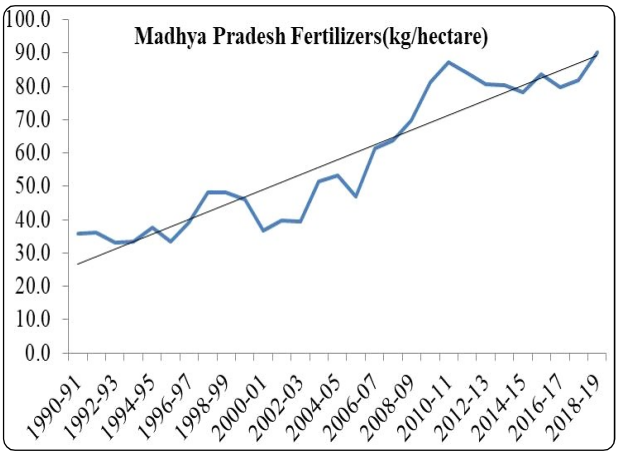

Fig. 5 : Consumption of fertilizers (kg/hectare) in Madhya Pradesh

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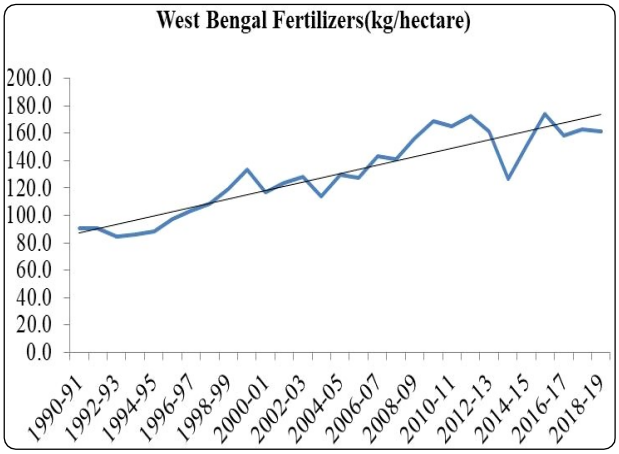

Fig. 6 : Consumption of fertilizers (kg/hectare) in West Bengal

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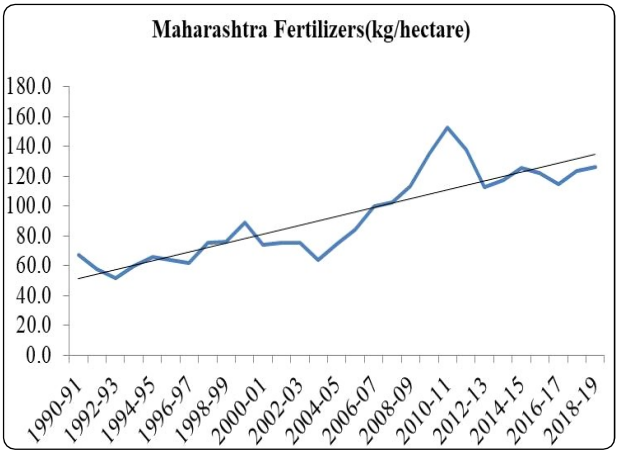

Fig. 7 : Consumption of fertilizers (kg/hectare) in Maharashtra

Source : https://www.rbi.org.in/ScriptsPublications View. aspx?id=20070

Madhya Pradesh, in Madhya Pradesh fertilizer consumption is also increasing yearly. Wheat, pulses, and rice are very important crops for human survival in India. These crops are consumed in all regions of India. A high consumption of chemical fertilizers used for the production of daily consumed crops damage the human health.

Graphical Representation of the use of Fertilizers for the Top States in Terms of Popular Fruits in India : In this section, fertilizers consumption data is graphically represented for the states Maharashtra, Tamil Nadu, Andhra Pradesh and Jammu and Kashmir, which produces a large number of fruits in India.

In Fig. 7 to Fig. 10, fertilizers consumption trends of Maharashtra, Tamil Nadu, Andhra Pradesh and Jammu and Kashmir are shown. These states produce a large number of fruits in India. Maharastra is the second largest fruit producer after Andhra Pradesh in India. Apple is largely produced by the Jammu and Kashmir. 81 percentages of banana and mango are produced by the Tamilnadu. In all four states, we can see that fertilizer consumption is showing a linear positive growth which is very harmful to the environment, ecology and human health.

In Fig. 11, fertilizers consumption in India is compared with the countries like China, Brazil, USA and Australia. China, Brazil, USA, Australia and India are world's top five agricultural producing countries.

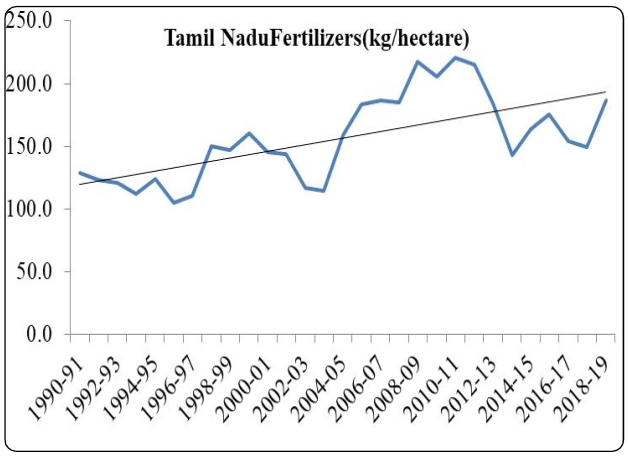

Fig. 8: Consumption of fertilizers (kg/hectare) in Tamil Nadu

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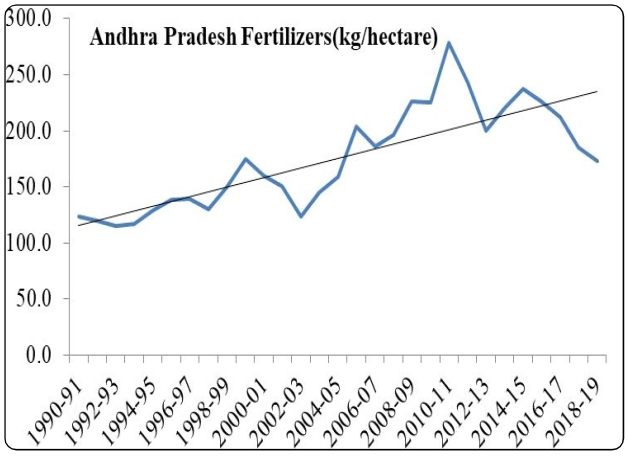

Fig. 9 : Consumption of fertilizers (kg/hectare) in Andhra Pradesh

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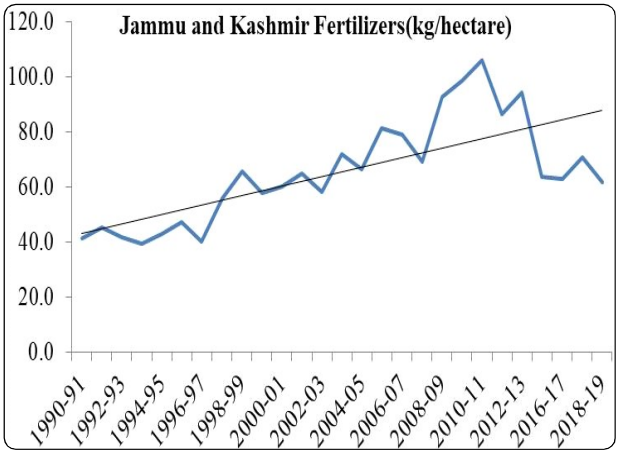

Fig. 10 : Consumption of fertilizers (kg/hectare) in Jammu and Kashmir

Source : https://www.rbi.org.in/ScriptsPublicationsView.aspx?id=20070

From Fig. 11, we can see that India is at third position after China and Brazil in fertilizers consumption worldwide. The USA and Australia are behind India. In China fertilizers consumption is more than 300 kg/hectare. In the last twenty years fertilizer consumption in India has shown a positive growth. Since India is also a highly populated country like China, fertilizers consumption is increasing yearly and in future it may be uncontrollable.

In this work, consumption of NPK fertilizers (kg/hectare) in India from 2001 to 2021 is examined. Using the method of least square a trend equation is developed for the historical data. According to the graph and trend equation, it is found that in India fertilizers consumption is increasing rapidly. According to the model expected fertilizers (NPK) consumption in India for the year 2030 and 2040 will be 164.81 kg/hectare and 384.41 kg/hectare respectively.

Fertilizers consumption in the five states of India, which produce the maximum daily consumable and essential agricultural products, following a linear increasing pattern. In Punjab and Haryana, it is an alarming condition where fertilizers consumption is crossing 250 (kg/hectare). Fertilizers consumption in the five states that produce the maximum fruits in India follows a linear positive trend. In Fig. 11, a comparative graph of the consumption of fertilizers

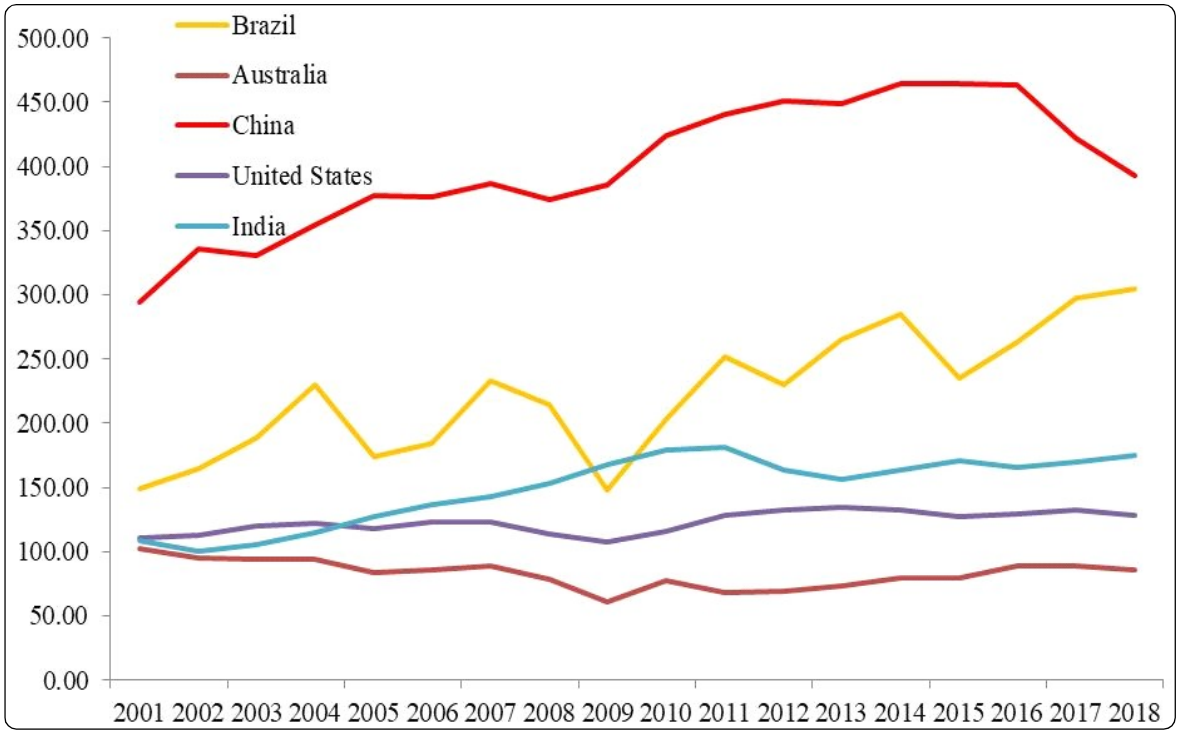

Fig. 11 : Comparison of consumption of fertilizers (kg/hectare) in India with other countries

Source : https://data.worldbank.org/indicator/AG.CON.FERT.ZS

in India and other four countries like USA, China, Australia and Brazil is plotted and it is found that in India average fertilizers consumption is more than USA and Australia. As excessive use of fertilizers affects the environment and human health, the consumption of chemical fertilizers should be controlled.

References

Alam, S. K., Li, P. and Fida, M., 2024, Groundwater nitrate pollution due to excessive use of N-fertilizers in rural areas of Bangladesh: pollution status, health risk, source contribution and future impacts. *Exposure and Health*, **16** (1) : 159 - 182.

Cha, V. M., Elish, T., Sina, N., Mishra, S., Kushwaha, A., Ekka, S. K. and Kujur, R., 2024, A review on organic farming in India. *Asian J. Biology*, **20** (2) : 19 - 24.

Choudhary, A., Ali, A. S. and Ali, S. A., 2014, Adverse health effects of organophosphate pesticides among occupationally exposed farm sprayers: A case study of Bhopal Madhya Pradesh, India. *Asian J. Biomedical and Pharm. Sci.,* **4** (35) : 29 - 34.

Devi, P. I., Manjula, M. and Bhavani, R. V., 2022, Agrochemicals, environment and human health. *Annual Review of Environment and Resources*, **47** : 399 - 421.

Dhankhar, N. and Kumar, J., 2023, Impact of increasing pesticides and fertilizers on human health: A review. *Materials Today* : *Proceedings.*

Getahun, E. and Keefer, L., 2016, Integrated modeling system for evaluating water quality benefits of agricultural watershed management practices: A case study in the Midwest. *Sustainability of Water Quality and Ecology,* **8** : 14 - 29.

Kumar, S., Sharma, A. K., Rawat, S. S., Jain, D. K. and Ghosh, S., 2013, Use of pesticides in agriculture and livestock animals and its impact on the environment of India. *Asian J. Env. Sci.,* **8** (1) : 51 - 57.

Kumari, K. A., Kumar, N. and Rao, N., 2014, Adverse effects of chemical fertilizers and pesticides on human health and environment, National seminar on impact of toxic metals, minerals and solvents leading to environmental pollution-2014. *Journal of Chem. and Pharm. Sci.*, **3** : 150 - 153.

Miah, S. J., Hoque, A., Paul, A. and Rahman, A., 2014, Unsafe use of pesticide and its impact on health of farmers: A case study in Burichong Upazila, Bangladesh. *IOSR J. Env. Sci., Toxicology and Food Tech.,* **8** (1) : 57 - 67.

Nicolopoulou-Stamati, P., Maipas, S., Kotampasi, C., Stamatis, P. and Hens, L., 2016, Chemical pesticides and human health : The urgent need for a new concept in Agriculture. *Front Public Health,* **4** : 148.

Pahalvi, H. N., Rafiya, L., Rashid, S., Nisar, B. and Kamili, A. N., 2021, Chemical fertilizers and their impact on soil health. Microbiota and Biofertilizers. *Ecofriendly tools for reclamation of degraded soil environs,* **2** : 1 - 20.

Patra, S., Mishra, P., Mahapatra, S. C. and Mithun, S. K., 2016, Modeling impacts of chemical fertilizer on agricultural production: A case study on Hooghly District West Bengal India. *Modeling Earth Systems and Environment*, **2** : 1 - 11.

Ramalingam, S., Panneerselvam, B. and Kaliappan, S. P., 2022, Effect of high nitrate contamination of groundwater on human health and water quality index in semi-arid region, South India. *Arabian J. Geo. Sci.,* **15** (3) : 242.

Sharma, N. and Singhvi, R., 2017, Effects of chemical fertilizers and pesticides on human health and environment : A Review. *International J. Agriculture, Environment and Biotechnology,* **10** (6) : 675 - 679.

Srivastav, A. L., 2020, Chemical fertilizers and pesticides: role in groundwater contamination. In Agrochemicals detection, treatment and remediation, pp. : 143 - 159.

SRIVASTAV, A. L., PATEL, N., RANI, L., KUMAR, P., DUTT, I., MADDODI, B. S. AND CHAUDHARY, V. K., 2024, Sustainable options for fertilizer management in agriculture to prevent water contamination: A review. *Environment, Development and Sustainability,* **26** (4) : 8303 - 8327.

THUY, T. T., 2015, Effects of DDT on environment and human health. *Journal Education and Social Sci.,* **2** : 108 - 114.

TRIPATHI, S., SRIVASTAVA, P., DEVI, R. S. AND BHADOURIA, R., 2020, Influence of synthetic fertilizers and pesticides on soil health and soil microbiology. In Agrochemicals detection, treatment and remediation (pp. : 25 - 54). Butterworth-Heinemann.

TYAGI, J., AHMAD, S. AND MALIK, M., 2022, Nitrogenous fertilizers: Impact on environment sustainability, mitigation strategies and challenges. *International J. Env. Sci. and Tech.,* **19** (11) : 11649 - 11672.

VINOTHKANNA, S., RAJEE, R. AND SENTHILRAJA, K., 2020, Assessing ground water quality for the suitability of irrigation in Dindigul District, Tamil Nadu, India. *Indian J. Ecology,* **47** (1) : 23 - 29.

WANG, Y. AND LU, Y., 2020, Evaluating the potential health and economic effects of nitrogen fertilizer application in grain production systems of China. *Journal of Cleaner Production,* **264** : 121 - 635.

YARGHOLI, B. AND AZARNESHAN, S., 2014, Long-term effects of pesticides and chemical fertilizers usage on some soil properties and accumulation of heavy metals in the soil (a case study of Moghan plain's (Iran) irrigation and drainage network). *International J. Agri. and Crop Sci.,* **7** (8) : 518 - 523.

https://www.ceicdata.com/en/india/chemical-fertilizers-nitrogen-phosphate-and-potash-npk-consumption-by-regions/chemical-fertilizers-npk-consumption-all-india

https://www.rbi.org.in/Scripts/PublicationsView.aspx?id=20070

https://www.faidelhiorg/general/Fert-use-Evironmental-qualitypdf

https://www.mrbiorgin/Scripts/PublicationsViewaspx?id=18877

https://data.worldbank.org/indicator/AG.CON.FERT.ZS