

THE EFFECT OF SUSTAINABLE AGRICULTURE PROGRAMS ON CHEMICAL FERTILIZER CONSUMPTION PATTERNS IN FARMERS

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ABSTRACT:

Background: Fertilizers are essential to achieve food security by enhancing crop growth. The selection of chemical fertilizers over organic fertilizers brings environmental consequences. The government is trying to achieve food security and promote organic fertilizers over chemical fertilizers by implementing various programs.

Aim: The study is carried out to understand the effect of government policies on farmers' chemical fertilizer consumption patterns.

Design: The publicly available data on the All-India consumption of fertilizer nutrients are collected from The Fertilizer Association of India. All the values from FAI data are in '000 tonnes as used in the text. The data of fifteen years (2007-08 to 2021-22) of chemical fertilizer consumption was divided into three sub-groups of 5-year durations each. Statistical analysis was done to understand the trend of chemical fertilizer consumption by the farmers. The data collected were subjected to tabular analysis and year-wise growth rate analysis. In tabular analysis, the difference in consumption for the current year and the previous year as well as the average consumption of chemical fertilizer per year were analysed and the growth rate was studied.

Results: The analysis of data clearly shows the steadily increasing pattern of chemical fertilizer consumption. In the five-years period, from 2007-2012, the total quantity of fertilizer consumed was 129878 tonnes. and the average quantity of chemical fertilizer consumed per year was 25,975.6 tonnes. From 2012 to 2017, the total chemical fertilizers consumed was 128302.4 tonnes, whereas 25,660.48 tonnes were used per year. The results for the year 2017-2022 showed mixed trends.

Conclusions: The study clearly shows that there is no effect of sustainable agriculture policies framed by the government on the consumption of chemical fertilizers by farmers. Across the study period, farmers were inclined to use chemical fertilizers, related to a lack of awareness of the principles of appropriate fertilizer management that can limit environmental damage.

KEY-WORDS: Fertilizers, agriculture, Sustainable Development Goals (SDGs), Environmental Health, Organic fertilizers.

1. INTRODUCTION

Sub-Saharan African countries and South Asian countries like India, Bangladesh, Nepal, and Sri Lanka give heavy subsidies on chemical fertilizers to farmers. The main aim of these subsidies is to increase crop yield to increase farmers' income and food security (Ricome et.al., 2024).

India is home to one-sixth of the global population and holds the key to the success of the United Nations 2030 agenda or sustainable development goals (SDGs). The 17 SDGs emphasize the interconnected environmental, social, and economic aspects of sustainable development by putting sustainability at their centre (Schleicher, 2018). SDG 2 is to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (UNDP, 2020).

SDGs were formulated in 2015 by the United Nations General Assembly (UNGA), but India has been trying to achieve national food security along with sustainable agriculture from the year 2007. The efforts of the Indian government were similar to SDG 2 targets. From year 2007 to 2023, the Government of India launched various programs in this direction. In 2007, the National Agriculture Development Programme (RKVY) was launched. National Project on Management of Soil Health & Fertility (2008-2009), National Mission for Sustainable Agriculture (2014-2015), and recently Paramparagat Krishi Vikas Yojana was launched in 2023. Studying the performance of such programs is necessary for fact-based discussions in sessions of parliament similar to the farmer's issues like pesticide management (Sarkar, 2011) or access to quality seeds (Sarkar, 2012), etc. Consequently, a better policy can be formulated to achieve the desired goals.

The United Nations predicts that India needs to produce 50% more food by 2050 to feed another 2.5 billion people (FAO, 2017b). To achieve food security, improving agricultural production is necessary (Pawlak, 2020). Innovations like farming the sea (Schubel & Thompson 2019; Sarkar, 2021), precision farming (Ericson & Fausti, 2021), permaculture (Kurniawati et al 2022), vigour maintaining seeds (Finch-Savage & Bassel, 2016; Sarkar, 2011) and advancing genetic selection technologies (Qaim, 2020; Shabnam et. al, 2011) need to be implemented.

Whatever would be the farming method,

fertilizers are one of the important factors affecting agriculture as well as the environment (Li and Wu, 2008; Savci, 2012). The use of organic fertilizer has contributed significantly to environmental sustainability and increasing agricultural production. So, to lessen the negative environmental impact of chemical fertilizers, replacing chemical fertilizers with organic fertilizers is a good choice for farmers (Wang et. al, 2018).

Urea, Diammonium phosphate (DAP), and Muriate of potash (MOP) are commonly used chemical fertilizers in India. Urea accounts for 82% of the total consumed nitrogen fertilizers. Not only in India but throughout the world urea is the most widely used chemical fertiliser.

Crops can take up only 30-50% of chemical fertilizers, and many of the applied components are lost in the soil polluting groundwater (Link et al., 2006). Excessive fertilization causes soil salinity, heavy metal accumulation, water eutrophication, and accumulation of nitrate. It gives out gases like nitrogen and sulfur, leading to air pollution and can indirectly lead to the greenhouse effect. Climate change affects how farmers use fertilizer and fertilizer overuse can contribute to further climate change (IFC, 2023).

In such situations, it becomes necessary to understand the patterns of chemical or synthetic fertilizer (NPK) consumption over a period of time. To date, there are few studies available showing the pattern of chemical fertilizer consumption by Indian farmers. But most of these studies are either showing intra-state variations in chemical fertilizer consumption patterns (Bora, 2022; Chand & Pavithra, 2015) or chemical fertilizer consumption patterns for specific states or agricultural zones (Usama & Khalid, 2018; Bagal et. al, 2018; Suryawanshi, 2015). Some of the studies are carried out to study the determinants of fertilizer consumption (Jadhav & Ramappa, 2021; Waghmode et. al, 2020). However, there is hardly any study available which shows the national level chemical fertilizer consumption pattern specifically after year 2007, when India has decided to achieve food security along with agricultural sustainability.

This study mainly focuses on the exact quantity of chemical fertilizer consumption at the national level on a year-on-year basis specifically after the year 2007. Our main purpose is to comprehend whether there is any impact of the government's

sustainable agriculture program on the behavior of farmers while choosing between organic or chemical fertilizers. Consumption pattern of chemical fertilizer mainly after the year 2007 was studied when the government announced various programs for sustainable agricultural development. This study of the trend in the consumption of chemical fertilizers from the year 2007 will help to understand the impact of the government programs on the choice of farmers, to understand factors responsible for the consumption of synthetic fertilizers by farmers, to promote organic fertilizers and to design future policies to achieve food security with agriculture sustainability.

2. METHODS

In the present study, secondary data were used to evaluate the trend in chemical fertilizer consumption in India for the period 2007-2022.

The data on the All-India consumption of fertilizer nutrients are collected from The Fertilizer Association of India <https://www.faidelhi.org/general/con-npk.pdf>. The Fertilizer Association of India (FAI) is a non-profit and non-trading company representing mainly fertilizer manufacturers, distributors, importers, equipment manufacturers, research institutes, and suppliers of inputs. The Association was established in 1955 with the objective of bringing together all concerned with the production, marketing, and use of fertilizers. This study carried out the analysis of fertilizer consumption in India from the year 2007-08 to 2021-22. For the convenience of the analysis, the total time of the study is divided into three subgroups of 5-year duration each.

The data collected were stored, tabulated, and analyzed. The total quantity of fertilizer (N+P₂O₅+K₂O) used per year is considered for the analysis. Keeping in view the study specific

objectives, the data collected were subjected to tabular analysis and year-wise growth rate analysis (Wayne & Chad, 2014). In tabular analysis, the difference in consumption for the current year and previous year as well as the average consumption of chemical fertilizer per year were analysed and growth rate was studied by following the formula:

$$\text{Growth Rate} = \frac{V_{\text{current}} - V_{\text{previous}}}{V_{\text{previous}}} \times 100$$

The average consumption of chemical fertilizers per year for the period of five years is calculated by the formula:

$$\begin{aligned} \text{Average} &= \frac{\text{Sum of all observations}}{\text{Total number of observations}} \\ &= \frac{a_1 + a_2 + a_3 + \dots + a_n}{n} \end{aligned}$$

All the values from FAI data are in '000 tonnes as used in the text.

3. RESULTS

The fertilizer consumption results for the 5 years (2007-2012) of analysis showed increasing trends (Table 1). But the maximum consumption of chemical fertilizer in these five years was in the year 2008-2009. This is the year when the National Project on Management of Soil Health & Fertility (2008-2009) was launched and just a year after the launch of the National Agriculture Development Programme (RKVY, 2007). In the year 2011-2012, fertilizer consumption is reduced as compared to the previous year (2010-2011). In the five-year period, from 2007-2012, the total quantity of fertilizer Consumed was 129878 tonnes, whereas the average quantity of chemical fertilizer consumed per year was 25,975.6 tonnes (Table 4).

Table 1: Chemical fertilizer consumption pattern in India for the period (2007-2012)

Sr. No.	Year	Quantity of Fertilizer Consumed ('000 tonnes)	Difference from Previous Year 21651.0 (2006-2007) '000 tonnes	Annual Growth Rate
1	2007-2008	22,570.1	919.1	4.25
2	2008-2009	24,909.3	2339.2	10.36
3	2009-2010	26,486.4	1577.1	6.33
4	2010-2011	28,122.2	1635.8	6.18
5	2011-2012	27,790.0	-332.2	-1.18

When the analysis was done for the period from year 2012 to year 2017, the decreasing consumption trend was noticed (Table 2). In these five years, comparatively lowest quantity of chemical fertilizer

(24,482.4 tonnes) was used in the year 2013-2014. In this five-year period of 2012-2017, the total chemical fertilizers consumed was 128302.4 tonnes, whereas 25,660.48 tonnes were used per year.

Table 2: Chemical fertilizer consumption pattern in India for the period (2012-2017)

Sr. No.	Year	Quantity of Fertilizer Consumed ('000 tonnes)	Difference from Previous Year '000 tonnes	Annual Growth Rate
1	2012-2013	25,536.2	-2253.8	-8.11
2	2013-2014	24,482.4	-1053.8	-4.12
3	2014-2015	25,581.3	1098.9	4.49
4	2015-2016	26,752.6	1171.3	4.58
5	2016-2017	25,949.9	-802.7	-3.00

The results for the year 2017-2022 are showing mixed trends (Table 3). In the years 2017 to 2019, the chemical fertilizer consumption was more or less similar. But the values have shown a dramatic increase in the year 2019-2020 (29,370.4 tonnes) and year 2020-2021 (32,535.6 tonnes). Year 2020-2021 has seen the highest chemical fertilizer

consumption in the total study period of fifteen years. Again, in the year 2021-2022, the chemical fertilizer consumption has reduced substantially. The total chemical fertilizer consumed in this period was 145523.9 tonnes, whereas the average quantity of fertilizer consumed per year in this period was 29,104.78 tonnes.

Table 3: Chemical fertilizer consumption pattern in India for the period (2017-2022)

Sr. No.	Year	Quantity of Fertilizer Consumed ('000 tonnes)	Difference from '000 tonnes	Annual Growth Rate
1	2017-2018	26,593.4	643.5	2.48
2	2018-2019	27,228.2	634.8	2.39
3	2019-2020	29,370.4	2142.2	7.87
4	2020-2021	32,535.6	3165.2	10.78
5	2021-2022	29,796.3	-2739.3	-8.42

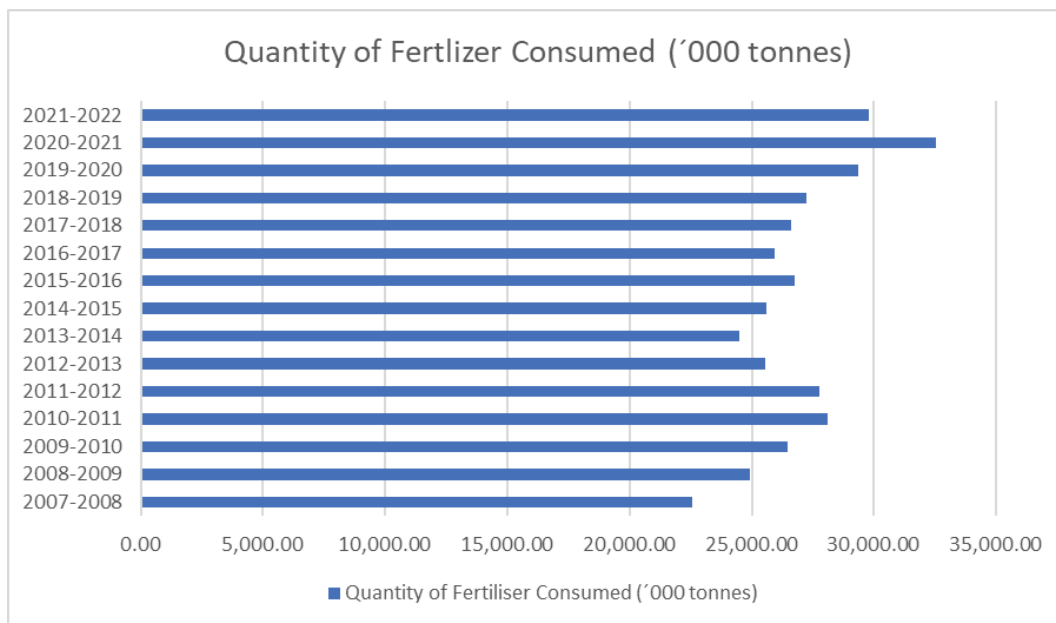


Fig.1. Quantity of fertiliser consumed ('000 tonnes) per year over the period of fifteen years

Table 4: Total quantity of fertilizer consumed in five years and average quantity of fertilizer consumed per year

Sr. No.	Period	Total quantity of Fertilizer Consumed ('000 tonnes)	Average quantity of Fertilizer Consumed per year ('000 tonnes)
1	2007-2012	129878.0	25,975.60
2	2012-2017	128302.4	25,660.48
3	2017-2022	145523.9	29,104.78

4. DISCUSSION

In 2007, National Agriculture Development Programme (RKVY) was launched. The main objective of this program was to increase the productivity of important crops through focused interventions and maximizing returns to farmers. After a year or so in the year 2008-2009, to improve soil health through green manuring, the National Project on Management of Soil Health & Fertility was launched. Both these programs are important from agriculture sustainability and environmental management point of view. The reason behind implementing these programs might be through the Xith – five-year plan, the Government of India was trying to achieve a 4% increase in agricultural growth while focusing on environmental sustainability.

The study is mainly carried out to understand

whether the government agriculture programs affect the chemical fertilizer consumption of Indian farmers or not. The results of the study have shown steadily increasing trends in chemical fertilizer consumption in India over the last fifteen years.

The analysis of years 2007-2012 shows, that after launching these two crucial national programs there was an increasing trend in chemical fertilizer consumption. Many studies say subsidy is one of the major reasons for the increasing trend of chemical fertilizer consumption (Chand & Pandey, 2008; Praveen & Singh, 2023). If so, then it is important to consider in the study period, that in certain years, the chemical fertilizer consumption has reduced in India. In the year 2011-2012, chemical fertilizer consumption was reduced by an annual growth rate of -1.18. The possible reason behind this might be, in year 2011-12 India saw extremely dry events or drought (Udmale *et. al*, 2015).

The analysis of data for the year 2012–2017 shows a slight reduction in the consumption of chemical fertilizers as compared to the period 2007–2012. The possible reason behind this trend might be the implementation of National Mission for Sustainable Agriculture (NMSA) in the year 2014–2015. Soil Health Management (SHM) is one of the most important interventions under this Mission. SHM aims at promoting location as well as crop-specific sustainable soil health management, creating and linking soil fertility maps with macro-micro nutrient management, judicious application of fertilizers, and organic farming practices. These efforts of the government might have helped in a slight reduction of chemical fertilizer consumption during this period.

The results for the years 2017–2022 have shown a considerable increase in consumption of chemical fertilizers as compared to the periods 2007–2012 and 2012–2017. Though the analysis shows comparatively lower consumption in the period 2007–2012 and 2012–2017, chemical fertilizer consumption in India in the last fifteen years has increased steadily with slight variations. There is hardly any inclination towards the use of organic fertilizers (manure).

Similar results were found in the comparative study carried out for India, Bangladesh and Nepal for chemical fertilizers used for Rice and Wheat crops (Aryal et. al, 2021). Here, farmers in focus groups indicated that their use of manure was decreasing over time in all three countries. They reported that educated young household members are less interested in carrying manure to plots, and as a result, the use of chemical fertilizer is increasing over time. Economic and elements of social capital are primarily positively correlated with increased chemical fertilizer use. Their study also suggests wealth, gender, education, migration for employment, access to the market, training, and off-farm income sources are some of the key factors influencing the application of chemical fertilizers.

Another study carried out in Iran to analyse the factors affecting the level of water resources pollution caused by the amount of chemical fertilizer consumed by farmers shows that variables such as main activity, farmers' experience, farmers' education, awareness of organic farming, income, price of fertilizers, and irrigation methods have

a significant effect on the level of consumption of chemical fertilizers by farmers (Mohammadi et. al, 2017).

Understanding the determinants for a farmer's choice of chemical fertilizer over organic fertilizer can help to reduce the consumption of chemical fertilizers. This is relevant for informing policy-making towards the negative environmental impacts and may help to achieve sustainable agriculture development goals, such as the zero growth of chemical fertilizers and pesticides, and recycling of animal and plant waste (MOA, 2015).

A study carried out on Chinese farmers' different fertilizer investment behaviours has discussed interesting facts (Chen et. al., 2018). Environmental friendliness appeared to be unattractive to farmers, who may usually be myopic in developing countries and may need community-level coordination in providing environmental goods that benefit themselves in the long run (Dong et. al., 2013; Huang et. al., 2015).

A study carried out in the Indo-Gangetic Plain (IGP) where the externalities of excessive use of chemical fertilizers for cereal production manifest in pollution highlights an interesting fact. Here, researchers studied the determining factors for the adoption of organic fertilizers in the region. Their study shows that only 32% of the farmers adopted organic fertilizers in the region whereas the rest are dependent on chemical fertilizers. Membership in farmer organizations, training, and education are the key variables that determine the adoption of organic fertilizers over chemical fertilizers. This study suggests the need for efficient extension efforts in organic fertilizers and suggests policy interventions that promote collective learning through farmer groups (Koovalamkadu et. al., 2021).

The adoption rate of organic fertilizer is low compared to the increasing usage of chemical fertilizer because many farmers fear the loss of crop output. Uncertainty can lead risk-averse farmers to apply more fertilizers and generate more pollution than in the certainty case (Isik et. al., 2003). Perceived high cost and long payback periods are also barriers of investment in organic fertilizer (Hou et. al, 2018).

A study was carried out with farmers of Denmark to understand their current use of organic fertilizer,

their interest in using alternative types in the future, and their perception of the most important barriers or advantages of using organic fertilizers. Almost three-quarters of respondents (72%) used organic fertilizer, and half of the arable/horticultural farms (without livestock) used unprocessed manures, suggesting significant manure exchange from animal production farms to arable farms in Denmark. The most important barriers to the use of organic fertilizer identified among these respondents were an unpleasant odour for neighbours, uncertainty in nutrient content, and difficulty in planning and use. Improved soil structure was clearly chosen as the most important advantage or reason to use organic fertilizer, followed by low cost to buy or produce, and ease of availability. Consequently, Danish government policies aim to increase in manure processing (Case et. al., 2017).

India, the world's second-largest chemical fertiliser consumer after China, has introduced many policies to regulate or reduce its use. The study at hand clearly shows that national sustainable agriculture policies do not affect farmers' consumption of chemical fertilizers. Across the study period, farmers reported being inclined to use chemical fertilizers. The main reasons for this are farmers' reluctance to take the risk of using organic fertilizers over chemical fertilizers and farmer's income expectations. For increase agriculture production and income, over the decades, the government promoted subsidies on chemical fertilizers which stimulated an increase in the use of chemical fertilizers. But with time, chemical fertilizers negative impacts on the environment have become prominent. Consequently, to minimize pollution and to achieve agriculture sustainability there is a need to reduce chemical fertilizers using multiple government policies.

Government needs to frame different types of policies mainly regulatory, incentive, and awareness policies. There is a need to frame policies related to awareness of the principles of appropriate fertilizer management that can limit environmental damage. The government needs to sensitize farmers by educational programs highlighting measures to improve nutrient-use-efficiency and reduce the negative impact of chemical fertilizer overuse.

The Ministry of Agriculture has to develop a central

action plan for achieving 'low to no' chemical fertilizers. Under the guidance of the central policy local governments, every province has to introduce their own action plans to guide and support the farmers in minimizing the chemical fertilizers. The government needs to provide economic incentives to farmers to shift from chemical fertilizers to organic fertilizers. These incentive policies should be supported by publicity or awareness policies.

The success of these policies depends on the farmers' response to these programs. Farmers will accept these policies only if they are convinced of high benefits and low costs of implementation.

Policies framed for reducing chemical fertilizer use need more research work in the future as it will have certain effects. Successful implementation of organic fertilizers will improve soil conditions and increase crop yield. However, these benefits will need a long time to take place. Though this will carry certain levels of risks and uncertainties for farmers, researchers need to work on these risks and uncertainties. They need to convey their research data to the government from time to time to make policy modifications. In-depth research is needed on farmers' individual characteristics, land management methods, and other determinants for farmers' choice of chemical fertilizers.

5. CONCLUSIONS

This study clearly shows that chemical fertilizer consumption has increased steadily over the last fifteen years in India. For the study period, from 2007 to 2022, the chemical fertilizer consumption increased from 22,570.1 to 29,796.3 ('000 tonnes). There is no effect of national sustainable agriculture policies on the choice of chemical fertilizer consumption of Indian farmers. Subsidy on fertilizers is not the only reason behind the increasing use of chemical fertilizers over organic fertilizers. Region-specific determinants for the choice of chemical fertilizers need to be studied. To achieve environmental management and agricultural sustainability goals, policies need to be framed to educate the farmers for long-term gains in their choice of fertilizer. The government should strengthen policies and use comprehensive means to encourage the reduction of chemical fertilizer use. Studies in other countries show farmers' risk attitudes have a significant impact on the choice of fertilizers, hence further programs are

recommended to educate the farmers. This can be explored to cover under the agriculture insurance system. The concerns of farmers about how organic fertilizers over chemical fertilizers will affect the crop yield will decide the success or failure of the government policies.

6. DECLARATIONS

- Ethics approval and consent to participate – Not Applicable
- Competing interests– The authors declare no conflicting interests
- Funding – Not Applicable
- Authors' contributions
1) Conceptualization, methodology, analysis and investigation: - Jaimini Sarkar
2) Original draft preparation, review and editing– Chiradeep Sarkar
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