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Increasing Agricultural Inputs: Autonomous Adaptive Response to Climate Change and Variability Effects in Selected South Asian Countries

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Abstract

The amount, duration, and timing of climatic factors like temperature, rainfall, and moisture are major determinants of crop production. In South Asia, more than 60% of agriculture is rainfed and susceptible to climate change and variability. Multiple climatic events, such as erratic and excessive rainfall, increasing temperature, longer dry spells, heat waves, and droughts, have had a major negative impact on production and farmers' livelihoods. Agricultural inputs are another major factor that determines agriculture production and productivity. This study explores the type of agricultural inputs, and utilization by smallholder farmers in the context of climate change and variability in selected study sites of three South Asian countries, Nepal, India, and Bangladesh. A descriptive exploratory research approach was adopted and the analysis is based on both primary and secondary data and document review. To comprehend the effects of climate change on agricultural input, we use a sample household survey of 633 farmers (211 in each country) together with six key informant interviews (KII) and three focus group discussions (FGD). The analysis of primary and secondary data *exhibits four key agriculture inputs, fertilizer, pesticides and insecticides, improved crop and seed varieties, and irrigation facilities. The limited use of modern tools and machinery is evident due to higher investment costs for resource-poor smallholder farmers. The increased use of fertilizer and pesticides adheres to the adverse effects of climate change and variability particularly decreasing crop yield and increasing rodents and pests. It is reasoned that increased use of selected input harms environment sustainability, crop production, and productivity in the long run. This study concludes that developing environment-friendly and climate-resilient inputs, regulatory monitoring for efficient and productive use of inputs, and ensuring the availability and affordability of agricultural inputs to all farmers are vital for environmental sustainability, and increased agriculture production and productivity.*

Keywords: *autonomous adaptation strategies, climate change and variability, crop production and productivity, maladaptation, resilient agriculture,*

Introduction

Agriculture is the historically dominant livelihood of the rural population of South Asia and nearly 42% of the total employment is in the agriculture sector, with Nepal comprising 61%, India with 44%, and Bangladesh with 35% of the total employment (World Bank, 2025). On the other hand, 65% of agriculture is still dependent on rainwater for irrigation making it one of the most vulnerable sectors (IPCC, 2023; Kattel, 2022). The amount, timing, and duration of selected climatic factors such as temperature and rainfall are major determinants, and variability in these factors impacts the quality and quantity of agricultural production (Din *et. al.,* 2022).

Agricultural inputs are crucial in agriculture production and productivity leading to food security. Agricultural inputs generally mean necessary supplies such as irrigation facilities, fertilizers, tools and machinery, seeds/saplings, plant protection agents, and labor (FAO, 2021). However, agricultural inputs increase expenses related to agricultural production, and efficient and cost-effective inputs are essential for the benefit of primary producers like smallholder farmers and consumers, besides the national economy. Farmers utilize various agricultural inputs in order to maintain or increase agriculture productions, improve quantity and quality of agriculture products and enhance livelihoods. Such type of action can be referred to as autonomous adaptation strategy of farmers (Stringer *et. al.,* 2020). Smallholder farmers in South Asian countries are particularly vulnerable to the effects of climate change-related challenges in the agriculture sector due to their heavy reliance on weather and climatic conditions, on one hand and agricultural inputs on the other, particularly for crop growth and increased production (Aryal *et al.,* 2019).

Due to such challenges farmers are abandoning the agriculture practices and shifting to other occupations. A declining number of farm households, decreasing average farmland holding, and changing crop cultivation practices is also noted by government authorities (NSO, 2024). In this context, the effect of climate change on agriculture practices, major adaptation strategies regarding crop production and productivity as well as response to climate change effect in agriculture practices becomes important research topic. This study explores the type of agricultural inputs, and utilization by smallholder farmers in the context of climate change and variability in selected study sites of three South Asian countries, Nepal India, and Bangladesh.

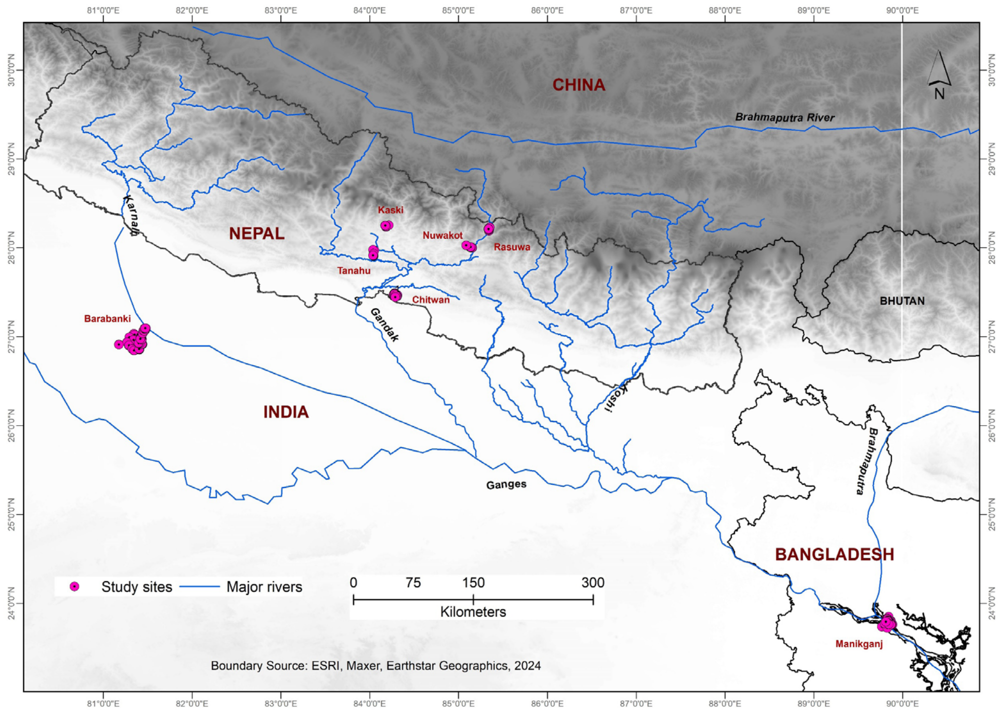
Study Area, Data, and Methods

The study area covers 47 villages in three South Asian countries, Nepal, India, and Bangladesh, and lies in the Indo-Gangatic-Brahmaputra Basin (Figure 1). The study area falls in the Monsoon region of South Asia with warm and wet summers and relatively dry winters and 80% of rain occurs during the monsoon (World Bank, 2024, 2021a, 2021b). Study sites in Nepal encompass 15 villages from five municipal units of which one is located in the Mountain eco-region (Gosainkunda in Rasuwa District), three in the Hill (Kispang in Nuwakot, Ghiring in Tanahu and Madi in Kaski District), and one in Tarai eco-region (Madi in Chitwan district). The elevation of these study sites ranges from 170 meters above mean sea level to 2700 meters with diverse climates ranging from sub-tropical (Madi in the Tarai Region) to Temperate (Gosainkunda in the Mountain region). All these sites lie within the Gandaki River Basin. Rainfall variability and extreme rainfall events are major climate change effects in these study sites followed by climate-induced hazard events like landslides, flooding, and soil erosion (GoN, 2021).

Study sites in India cover four sub-district-level administrative units within the Barabanki district of Uttar Pradesh. The study site here has uniform plain topography with average elevation ranging from 30 meters to 114 meters above mean sea level. This area is prone to climate-induced flooding and is highly vulnerable (VI 0.622) to climate risk, having more than 80% rainfed agriculture, and large yield variability (GoI, 2020). Study sites in Bangladesh lie in the confluence of the Padma (Ganges) and Jamuna (Brahmaputra) rivers which are flood-prone Char areas and identified as highly climate risk-vulnerable regions of Bangladesh. The field sites are spread over four unions, a sub-district level administrative unit within the Manikgunj district of Dhaka division. The dominant climate change effects in the study villages of Bangladesh are reported as river bank flooding, siltation and bank erosion, rainfall variability, and extreme heat-waves.

Figure 1

Location Map of Study Sites



The study is based on primary and secondary data sources. A descriptive exploratory research approach was adopted and the analysis is based on both primary and secondary data and document and paper review. All the documents related to climate change policy, adaptation plans and strategies, and action plans were reviewed together with the agriculture policies and strategies from national to local levels. Disaggregated data at community and household levels on the effects of climate change on crop and crop production, type and use of agricultural inputs, issues, and problems related to agriculture, etc. were obtained using different field research tools. Checklist was prepared for KII and FGD. A field survey questionnaire was used for household information collection. Informal discussion and community survey were carried out using the checklist.

A multi-stage purposive sampling method has been employed to select sample areas through spatial stratification. Since the total number of farm households was unknown, the sample size was determined using the latest available census data of the proportion of households engaged in agriculture for each country as a representative to the study sites estimated as 35% in Bangladesh to 61% in Nepal (World Bank, 2025). The representative sample constitutes about 5.8% of farm households in the study sites in

Nepal, 5.4% in India, and 5% in Bangladesh. Besides. meteorological station data were collected from 11 stations (1 from Bangladesh, and 5 each from India and Nepal) to analyze the trend in temperature and rainfall over three decades.

Results and Discussion

Climate Variability, Agriculture Production, and Productivity

The study found that the annual mean temperature in all Nepal and Bangladesh has slightly increased but slightly decreased in India while the overall rainfall amount is in a decreasing trend in all three countries. Annual total rainfall in Manikganj, Bangladesh declined by 616.4mm in-between 981(2368.9mm) to 2021(1752.5mm), while it declined only by 55.4mm between 1990 (1643.3mm) and 2020 (1588.2mm) in one of the study sites in Nepal (Madi in Chitwan district). In Barabanki of India, rainfall amount decreased by 451.3mm 1981(1500.3mm) and 2020 (1049mm). Minimum annual temperature increased by 0.1^{0}C between 1981 (21.4^{0}C) and 2021 (21.5^{0}C) in Manikgunj, Bangladesh while maximum annual temperature increased by 1.5^{0}C between the same period (from 29.5^{0}C in 1981 to 31.0^{0}C in 2021). In case of Chitwan district in Nepal, minimum temperature increased by 0.01^{0}C between 1990 (18^{0}C) and 2020 (18.1^{0}C) whereas increase of 0.7^{0}C in maximum annual temperature is noted between 1990 (30.5^{0}C) and 2020 (31.2^{0}C). In contrast, temperature data of India demonstrate slight decrease in both minimum and maximum annual temperature. In between period of 1981 (15.6^{0}C) and 2016 (14.9^{0}C), the minimum temperature decreased by -0.7^{0}C where during the same period maximum temperature decreased by 0.01^{0}C.

Major crop production in study countries include food crop, potato, oilseed and lentils followed by seasonal vegetables in selected sites, particularly in Bangladesh. The productivity of selected crops is presented in Table 1. Productivity is highest in Bangladesh among three countries. Productivity of potato is highest among all crops in three countries followed by Paddy and Maize.

Table 1

Productivity of Selected Crops in the Study Area

SN	Crop Type	Nepal	India	Bangladesh
1	Paddy	3.21	3.99	5.89
2	Wheat	1.82	3.49	1.89
3	Maize	2.51	2.50	3.92
4	Millet	1.67	-	4.00
5	Potato	7.82	6.74	10.34
6	Oilseed	1.02	1.23	1.54
7	Lentils	1.08	0.59	0.40

Source: Field Survey 2022-2023

Type and Utilization of Agricultural Inputs

Major agricultural inputs in the study area are found to be fertilizer, pesticides, improved crop and seed varieties, and irrigation systems. Farmers in the study sites reported that fertilizer use has increased by up to 80% since they started. Farmers in Bangladesh used an average of 320 kg per hectare of fertilizer five years ago but have increased their usage to 379 kg per hectare now; i.e., fertilizer use has increased by 19% in five years. In India, the average use of fertilizer was 176kg/hectare, which increased to 195kg/hectare in 2023. Though fertilizer use is less in India in comparison to Bangladesh, it has increased by nearly 10% in the last five years. Farmers in Nepal have relatively low use of fertilizer, with 114kg/hectare in 2022. But there has been an increase of 17% in the last five years, as the quantity was 94kg/hectare in 2017/18. Several modern tools and machinery are adopted by farmers, and the percent share of modern tools and technology use is highest among farmers in India, followed by Bangladesh. Nepal has a very low adaptation of modern tools and technology (Table 2). Among modern tools and machinery, the water pump is the most common tool in India and Bangladesh, while the tiller is the most widely used machinery in Nepal. A dryer is the least adopted machinery utilized by farmers among the three countries.

Table 2

Modern Tools and Machinery Adoption by Farm Household

SN	Tools/Machinery	Nepal	%	India	%	Bangladesh	%
1	Tiller	30	14.2	24	11.4	53	25.1
2	Tractor	6	2.8	46	21.8	25	11.8
3	Planting machine	1	0.5	11	5.2	1	0.5
4	Harvester	4	1.9	11	5.2	5	2.4
5	Thresher	5	2.4	8	3.8	8	3.8
6	Dryer	1	0.5	4	1.9	1	0.5
7	Sprinkle	2	0.9	3	1.4	12	5.7
8	Water pump	14	6.6	99	46.9	68	32.2
9	Other	7	3.3	2	0.9	0	0
	Total	70	33.2	208	98.6	173	82.0
	No tools and machinery	141	66.8	3.0	1.42	38	18.0

Source: Field Survey 2022-2023

Utilization of new agricultural inputs in the last 10 years varied with respect to the farming years. It is found that number of farmers introducing new agricultural input is relatively higher in India followed by Bangladesh in comparison ton farmers in

Nepal (Table 3). Similarly, adoption of new inputs is higher among famer with 15 to 30 years of farming experience. Of the total respondents (N=633), 39% reported that they have introduced new agricultural inputs in the last 10 years, but 61% have not adopted any new inputs. Country specific adoption is variable. Highest percentage (59.7%) of sampled farmer have adopted new inputs in Nepal in last 10 years and among them with more than 30 years' experience are dominated comprising 42.1%. Farmers of Bangladesh also depict similar characteristics with farmer having more than 30-years experiencing dominating adoption of new inputs. Adoption of new inputs is lowest among Indian farmers. Only 26. 1% of the sampled farmers have adopted new inputs in the last 10 years of which, 15 to 30-years' experience group constitute the majority. The major causes of low percentage of Indian farmers in adopting new inputs are outlined as financial constraints, less knowhow of modern inputs, uncertainty on tools and technology use and belief in traditional inputs and practices.

Table 3

New Input Adoption in Last 10 Years

Farming Years	Nepal		India		Bangladesh	
	Respondents	%	Respondents	%	Respondents	%
Up to 15 years	31	24.6	4	8.7	11	19.3
15-30 Years	42	33.3	27	58.7	23	40.4
>30 years	53	42.1	24	52.2	32	56.1
Total (N=211*3)	126	59.7	55	26.1	66	31.3
No new agriculture inputs in recent years	85	40.3	156	73.9	145	68.7

Source: Field Survey 2022, 2023

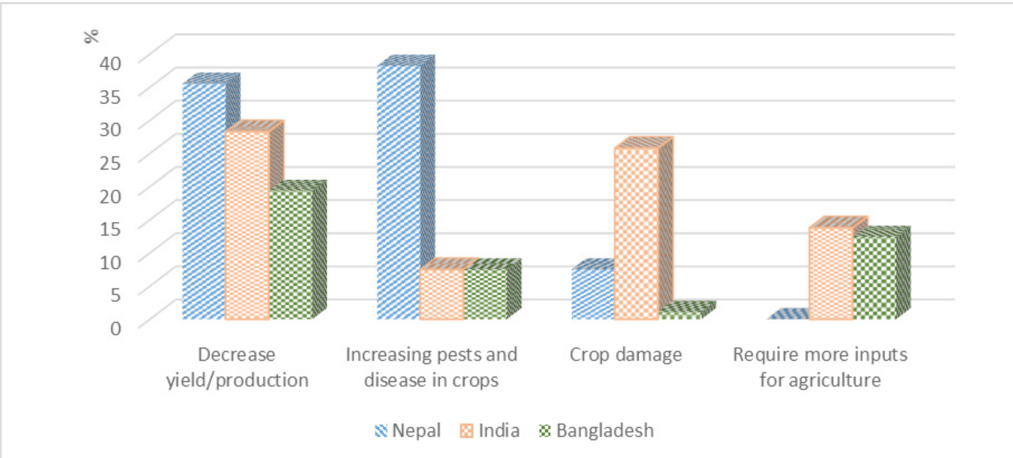
The Effects of Climate Change and Agricultural Input

The farmers have noticed that the major impact of climate variability on staple crops are, decrease crop yield and production. Increasing rodents and pests, increased input costs (Figure 3), followed by farmland abandonment and climate induced inundation and flooding in farmland.

The effect of climate variability was reported highest in reduced yield and 42.7% of respondents in Bangladesh, 40.8% in India, and 36% of farmers in Nepal reported that they had to increase agricultural inputs by 15 to 20 % from previous years to maintain the yield as previous years. The most common fertilizers used in all study sites are Urea, DAP (concentrated phosphorus and nitrogen), and Potash. Besides another major impact identified is farm land abandonment and labor migration in case of Nepal. It is found that 24.2% in Mountain, 21.8% in Hill, and 3.9% in Tarai Region have abandoned farmland due to reduced production, uncertain climate conditions, and uncertain agricultural market. Inundation and flooding of farmland are another experienced impact of climate change by farmers in India and Bangladesh. It is found that 21% farmers in India and 33% in Bangladesh have experienced frequent flooding and inundation in the last 10 years.

Figure 3

Experienced Effect of Climate Change and Variability



Discussion

Increased use of agricultural input has been reported in recent years due to various reasons and important among them is uncertain climatic effects. These effects have caused a significant increase in terms of agricultural inputs like fertilizers, pesticides, and insecticides, improved seed varieties, and farm machinery as immediate response and autonomous adaptation strategies (Chapagain *et al.,* 2025; Mistary, 2022). Likewise, the adoption of resilient crop varieties, including improved seed varieties has been regarded as one of the major coping strategies among South Asian farmers (Bhatta & Aggarwal, 2014). Studies carried out in Nepal, India, and Bangladesh have found that major climate change adaptation strategies of smallholder farmers range from changing crop types, using different crop varieties, increasing fertilizer use, increasing pesticides and insecticides, and adopting new tools and technologies (Hossain *et al.,* 2022; Karki *et al.,* 2020; Reddy & Dutta, 2018). The adoption of agriculture inputs such as improved seeds and inorganic fertilizers is high in countries where national subsidy programs are implemented (FAO, 2021). The Government of Nepal has allocated 208.4 million USD for chemical fertilizer subsidy which accounts for 49% of the total budget for agriculture and livestock development (MoALD, 2024). Similarly, in India, Thus, increasing fertilizer use can be ascribed to Government subsidies for fertilizer. However, this may have aided in a short-term upsurge in agricultural production, the negative effects of the persistent use of chemical fertilizers such as soil quality degradation, nutrient imbalance, and fertility, depleting groundwater quality, and human health problems have been reported, which requires additional cost investment for soil, water, and human health treatment (Hossain *et al.,* 2022). The findings of this study have also validated the results of previous studies with 80% of respondents confirming that there has been up to 62% increase in chemical fertilizer use in the last 10 years and up to 27% increase in pesticides and insecticides use. Increasing pesticide use due to increased pests and rodents requires change in temperature and rainfall pattern variability in climate has resulted in favorable conditions (Shake *et al.,* 2022;) for pests and rodents, and farmers are compelled to increase the insecticides and pesticide quantity as control measures. It has directly impacted the total cost of agriculture production, requiring higher investment from farmers and making them more vulnerable. Research carried out by FAO (2021) revealed that the percentage of small-scale farmers using essential inputs such as irrigation facilities is limited while inputs with government subsidies such as chemical and inorganic fertilizers are relatively higher. The current study confirms similar findings with more than 40% of respondents without new agriculture inputs in Nepal in the last 10 years, followed by nearly 74% of farmers in India and 69% in Bangladesh. Conversely, autonomous adaption of accessible agricultural inputs as immediate response to climate change effect is also ascribed to limited understanding and technical knowledge of farmers on long term climate change effect which has resulted maladaptive practices (Shrestha *et. al.,* 2024).

The government subsidies for improved seed varieties are planned adaptation strategies in all three study countries (GoI, 2020; MoEFCC, 2022; MoFE, 2021). Changing crop varieties and using improved seed varieties is another common autonomous response to climate change effects followed by fertilizer and pesticide use. The government subsidies on agricultural inputs like fertilizer and improved varieties as input subsidy policy have significantly increased the financial accessibility of marginal and smallholders by reducing the financial burden of resource-poor farmers. The rise in improved seed and crop varieties utilization as an autonomous adaptation can again be attributed to government subsidies and the effective implementation of the planned climate change adaptation strategies. However, subsidies in limited food crop varieties such as paddy, wheat, and maize have limited benefits for selective food-crop farmers with relatively larger land holdings and have excluded other cash crops and organic farmers with small landholdings in one hand and on the other, it has produced distortionary and counter-productive effects (Bista *et. al.,* 2016; Islam & Mujeri, 2021; Rakshit, 2018). Moreover, lack of proper regulation, standard guidelines or lapses in regulatory monitoring, and punishment for regulatory violation on the institutional front has resulted in maladaptation and adverse effects on the environment, human and plant health, and increased input costs contesting the other planned adaptation strategies of the Government like maintaining or improving environmental sustainability and economic security in agriculture (IPCC, 2022; Malik & Ford, 2024).

Demand of reliable irrigation facilities is rising due to shifting rainfall patterns, variability in rainfall amount, decreasing winter rainfall, and increased dry spells. National adaptation plan of all three study countries has outlined promotion of environment-friendly and sustainable irrigation system such as solar irrigation system and has provisioned subsidies to extent (GoI, 2020; MoEFCC, 2022; MoFE, 2021). However, limited farmers (less than 1 %) are using such input in case of Nepal and Bangladesh as compared to India (7.8%). Similarly, adoption of modern tools and technology as an agricultural input is constrained due to low know-how of technology based tools, uncertainty regarding technology and additional maintenance costs (Shrestha *et. al.,* 2024). The importance of awareness and skill development in adoption of modern tools and technology should be essential part of agricultural input subsidy policy.

Availability (supply) and affordability of agricultural input are found to be a major determinant for smallholder farmers to increase production and productivity. Smallholder farmers are likely to be resource-poor with low income and low savings. Though they have relatively fair access to basic inputs like crop and seed varieties, pesticides and fertilizers, they are constrained to use essential inputs such as modern efficient tools and machinery due higher cost. Access to agricultural input has remained another challenge in the study countries. Nepal has limited agricultural input production and is dependent on imported inputs, and farmers are at a disadvantage because they have to pay higher prices for imported inputs. Besides, physical inaccessibility to input supply services due to limited road and transportation facilities increases additional expenses. They are likely to be deprived of using mechanized tools and modern technology. In case of Bangladesh and India access to and adoption of modern tools and machinery has remained limited followed by irrigation facilities in contrast to other inputs.

Conclusion

Several studies reveal that government input subsidy policies as planned climate change adaptation strategies in terms of agricultural inputs have been effective in selected agricultural inputs and have benefited smallholder farmers and increased agricultural production to an extent. Climate-resilient hybrid crop varieties, fertilizers, and pesticides are becoming available. Despite these impressive implementation results and growth in production, there is a considerable gap remains in terms of environmental sustainability in the agriculture sector due to lapses in the institutional front on one side, and autonomous adaptation and disproportionate use of selected agricultural inputs ignoring regulations and guidelines from farmers' front has resulted in maladaptation. In this context, it is concluded that policies and strategies are required to divert input subsidies from less environment-friendly components (e.g. chemical fertilizer, pesticides) to environment-friendly and climate-resilient high value crop varieties, improved seed varieties, organic fertilizers, basic agriculture tools, and solar irrigation facilities by increasing financial accessibility to these agricultural inputs. Development of such inputs, monitoring of efficient and productive use of inputs, and ensuring the availability and affordability of agricultural inputs to all farmers are of crucial importance to environmental sustainability, increase agriculture production and productivity.

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