Crop Diversification in South Asia: A Panel Regression Approach

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Abstract:

South Asia's agricultural sector has experienced vigorous growth and structural transformation over the last few decades, albeit differently across the region. This study examines the crop diversification status and various determinants such as socioeconomic (per capita gross domestic product, population, arable land, and cropland), soil/agronomic (root zone moisture), agricultural inputs (fertilizer and pesticide consumption), the productivity of food and non-food crops, international trade, and climate (maximum and minimum temperature and rainfall) factors. The share of cereals has decreased in most countries, but they continue to dominate South Asian agriculture. The area under high-value crops in India has increased significantly, replaced the area under cereal cultivation during the study period. Similar results were seen in the Maldives, where vegetables replaced oilseeds. The Hausman model test suggested a random-effects model for the analysis of the determinants. All the determinants considered in the study explain 69 percent of the variation in the crop diversification index. The crop diversification in south Asia was influenced by per capita GDP, minimum temperature, pesticide consumption, food crop yield index, and non-food crop yield index during the study period. Cropland percentage and population, on the other hand, reduce the crop diversification. The price factor contributed more than half to agricultural growth. It remained the primary source of growth in all South Asian countries, followed by yield, which is identified as the second most crucial factor. The contribution of crop diversification to agricultural growth has been declining over time.

Keywords: Crop Diversification, Decomposition analysis, Panel Data Model, South Asia

1. Introduction

Agriculture growth is both essential and sufficient to initiate the structural transformation process, which results in agriculture's contribution of GDP falling from roughly 30% in 1970 to 17% in 2017 [1]. More than a quarter of the developing world's population lives in South Asia, and approximately 72 percent of them live in rural areas. However, in South Asia, majority (94%) of suitable agricultural land has already been cultured, leaving no scope to expand [2]. The South Asia's area under annual and permanent crops is expected to be 213 million ha (near half of total land area) by 2030, with only a minor increase [3].

Furthermore, new land area is primarily derived from pasture and forest land, implying substantial investments and some development foregone [4]. Since the late 1980s, South Asian economies have been undergoing economic reforms. Trade liberalization is being gradually incorporated into their policy framework. However, the ongoing globalization of agriculture has presented these countries' agrarian sectors with new challenges and opportunities.

Food security remains a critical issue in the subcontinent. Government policy continues to be obsessed with cereal self-sufficiency, which presumably contributes to a large portion of land being allocated to cereal crops. Countries such as Bangladesh, India, and Sri Lanka have achieved national food security, but the focus remains on increasing rice and wheat production. Nations with food grain production deficits, such as Bhutan, Nepal, and Pakistan, are making serious efforts to increase production [5]. The current situation in the South Asian region raises severe concerns about overexploitation of natural resources, rural employment, the livelihood of agriculturist farm households, food security, and sustainability.

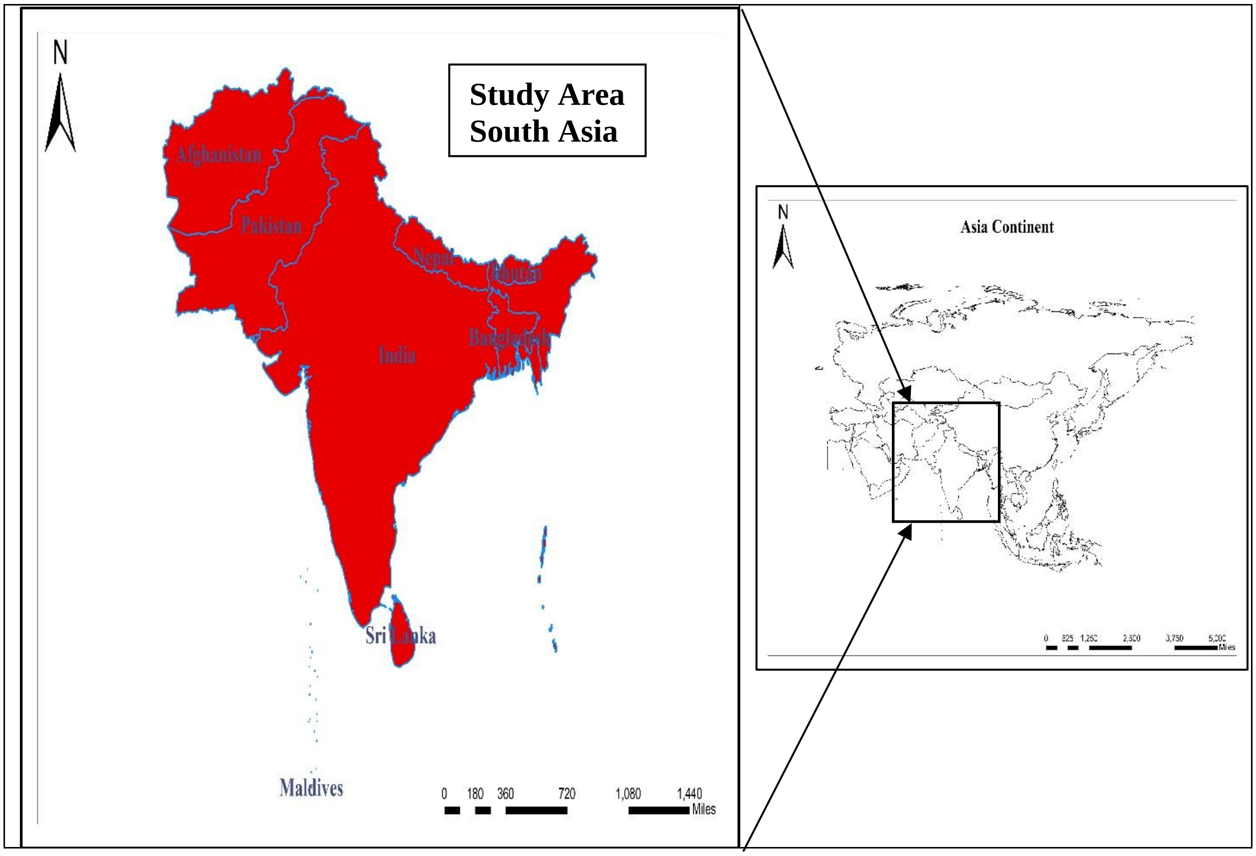
Crop diversification has enormous potential as an economic driver within the agricultural sector, which could be critical in meeting the challenges discussed earlier in this study. It has also become a vital component for achieving higher output growth, increasing farm income, creating jobs, conserving precious soil and water resources, consumer preferences for high-value, nutrient-dense foods, rural livelihood, sustainable use of natural resources, and poverty alleviation [6-12]. It can be influenced by socioeconomic, soil and agronomic, agricultural inputs, productivity, international trade, and climatic factors, all considered in this study.

The South Asian developing region is characterized by limited access to financial and technological resources, which must be addressed in order to achieve quicker, more efficient, and sustainable agricultural expansion and accelerate the pace of structural transformation. The current research focuses on cropping pattern dynamics, agricultural diversification, and various determinants such as socioeconomic, soil/agronomic, agricultural inputs, the productivity of food and non-food crops, international trade, and climate factors. The study identifies crop diversification determinants in the South Asian region and crop diversification determinants by country. This paper also investigates the sources of agricultural growth in South Asian nations.

2. Materials and Methods

2.1 Study Area

The South Asian region, which includes Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka, was chosen for the study because it comprises more than twenty five percent of world's population, with 72 percent of them living in rural regions. [4].



2.2 The Data

Using time series data, this study examines agricultural transformations in South Asian countries from 1991 to 2020. FAO statistics released data on area, production, yield, arable land (ha/person), per capita gross domestic product, population, fertilizer (kg/ha), and pesticide (kg/ha) [2]. Data on exports and imports were obtained from UN Comtrade [13]. The NASA Power Data Access Viewer was used to download temperature (maximum and minimum), rainfall, and root zone moisture data for a different latitudes and longitude [14].

2.3 The Analytical Framework

Percentages, averages, and various analytical technique were used to study status of the South Asian agriculture. The cropping pattern of various South Asian countries were studied using the percentage share of commodity group.

2.4 Dynamics of Cropping Pattern

The dynamics of cropping patterns were studied in the four following decades, i.e., 1991-2000, 2001-2010, 2011-2020, and 1991-2020, using percent change and compound annual growth rates. The compound growth rates for various variables were calculated by fitting the exponential function to the figures of the area. The power function of the form $Y = ae^{bt}$ was fitted using the ordinary least square method [15-16]. It was converted into a log-linear function using the logarithmic transformation as follows:

$$\mathrm{Ln}(Y) = \mathrm{Ln}(a) + bt \qquad (1)$$

where

Y being the area and t being the time (1991 to 2020).

The following compound annual growth rate (CAGR) formula was used:

$$\text{CAGR} = \text{b} \times 100 \quad (2)$$

The significance of the CAGR was tested by using t-statistics.

2.5 Crop Diversification Index

The entropy index was employed in this study for optimal crop diversification index because, according to Samuelson's theorem, optimal diversification maximises the entropy index [15]. When diversification is perfect, the entropy index approaches one, and it approaches zero when it is highly specialized. Crop diversification was examined using the following formula:

$$\text{Crop Diversification Index} = \sum_{i=0}^{N} p_i \log \frac{1}{p_i} \quad (3)$$

where p_i indicates the proportion of area of the i^{th} crop, and i goes from 1,2,…,n [crops].

2.6 Determinants of Crop Diversification

Fixed effect models and random effect models were employed to analyse agricultural diversification drivers at the nation level in South Asia. A balanced panel data set, with equal observations for each country and a sample size of 3360 data points, was used. The Hausman specification test was used to assess the technique's suitability for data analysis in order to choose the best model between fixed effect models and random effect models. According to the Hausman test results, the chi-square value was non-significant, indicating that a random effect model is adequate for examining crop diversification determinants.

2.7 Random Effect Model

The random effect model (REM) implies that the individual-specific coefficient β_{1i} is fixed for each time-in-variant and that β_{1i} is a random variable with a mean value of β_1 and that the random intercepts changes between nations (cross-section units). Dummy variables are used for each country to designate a specific country. It permits heterogeneity or individuality across nations since each has its own intercept value. Different South Asian countries are undergoing different economic reforms and agro-ecological conditions for agriculture crops, so acreage transformation differs by country [11,12]. So, in the current study, the intercept varies across South Asian countries but not overtime. Consequently, the random effect model for panel data may be expressed as follows:

$$\begin{aligned} \text{EDI}_{it} = {} & \beta_1 + \beta_2\text{AL}_{it} + \beta_3\text{GDP}_{it} + \beta_4\text{CL}_{it} + \beta_5\text{POP}_{it} + \beta_6\text{MI}_{it} + \beta_7\text{MAXT}_{it} + \beta_8\text{MIN}_{it} + \beta_9\text{RZM}_{it} + \beta_{10}\text{RF}_{it} \\ & + \beta_{11}\text{F}_{it} + \beta_{12}\text{P}_{it} + \beta_{13}\text{FCYI}_{it} + \beta_{14}\text{NFCYI}_{it} + \beta_{15}\text{BGD}_{it} + \beta_{16}\text{BTN}_{it} + \beta_{17}\text{IND}_{it} + \beta_{18}\text{MDV}_{it} \\ & + \beta_{19}\text{NPL}_{it} + \beta_{20}\text{PAK}_{it} + \beta_{19}\text{LKA}_{it} + \text{w}_{it} \quad (4) \end{aligned}$$

where $w_{it} = \varepsilon_i + u_{it}$.

w_{it} = composite error term

ε_i= the cross-section or individual-specific error component

u_{it} = the combined time series and cross-section error component. Annex I presents the specification of variables and their predicted diversification indicators.

2.8 Merchandise Index

The merchandise index measures the magnitude of export market concentration by country of origin. The merchandise index had a positive relationship with the crop diversification index and influenced prices in the domestic market to increase crop diversification.

$$\text{Merchandise index} = \frac{X_k}{X_k - M_k} \quad (5)$$

where X_k is the export of the k-th agriculture commodity and M_k is the export of the k-th agriculture commodity.

2.9 Crop Yield Index

Determining the impact of all the food and non-food crop yields grown at the country's level, with average yields of the same crop grown in that locality, proves to be useful in our analysis, as explained below. The index is measured in terms of percentage. The crop yield index computation is discussed below:

$$\text{Production efficiency } (PF_i) = \sum_{i=0}^{n} \frac{AY_i}{PY_i} \times 100 \quad (6)$$

$$\text{Crop yield index} = \frac{\sum_{i=0}^{n} PF_i \times A_i}{\sum_{i=0}^{n} A_i} \quad (7)$$

where PF_i indicates the production efficiency of the i-th crop, Y_i denotes the country's actual yield of the i-th crop, PY_i implies the country's potential yield of the i-th crop, and A_i indicates the country's area of the i-th crop. Therefore, a high yield index for both food and non-food crops favorably affect the crop diversity index far more than yield improvements in monoculture systems.

2.10 Decomposition of Growth

To examine the share of various sources to agricultural growth, the "growth accounting" method [17,18] is used to dissect the total increase in agriculture. For instance, the rise or change in income from a single crop at two periods in time (or across time) may be broken down into the estimated impact of area, productivity, and price changes [1,19].

$$R_i = X_i \times Y_i \times Z_i \quad (8)$$

where X_i = the area of crop i, Y_i = yield of crop i, and Z_i = actual producer price of i crops, then the R_i from crop i may be stated as follows:

The total revenue is obtained by adding the revenues of n crops:

$$R = \sum_{i=1}^{n} X_i \times Y_i \times Z_i \quad (9)$$

A source of adjustment in the decomposition process of total revenue from n crops is crop diversification. For analyzing that, we state that the area under crop i as a proportion of total cropped area, and expressed as, $M_i = \left(\frac{X_i}{\sum_{i=0}^{n} X_i}\right)$, and substitute this in Eq (9):

$$\text{Revenue} = \left(\sum_{i=1}^{n} M_i \times Y_i \times Z_i\right) \sum_{i=0}^{n} X_i \quad (10)$$

By differencing both the sides of Eq. (10) we get the specific contribution of Area, Yield and Price

$$\partial R \cong \left(\sum_{i=1}^{n} M_i \times Y_i \times Z_i\right) \partial \left(\sum_{i=0}^{n} X_i\right) + \left(\sum_{i=0}^{n} X_i\right) \partial \left(\sum_{i=1}^{n} M_i \times Y_i \times Z_i\right) \quad (11)$$

The term $\left(\sum_{i=0}^{n} X_i\right) \partial\left(\sum_{i=1}^{n} M_i \times Y_i \times Z_i\right)$ of Eq. (11) can be decomposed as:

$$\partial R \cong \left(\sum_{i=1}^{n} M_i \times Y_i \times Z_i\right) \partial\left(\sum_{i=0}^{n} X_i\right) + \sum_{i=1}^{n} \partial\left(M_i \times Y_i \times Z_i\right) \quad (12)$$

Expanding the term $\sum_{i=1}^{n} \partial\left(M_i \times Y_i \times Z_i\right)$ from Eq. (12) we drive :

$$\partial R \cong \left(\sum_{i=1}^{n} M \times Y_i \times Z_i\right) \partial\left(\sum_{i=0}^{n} X_i\right) + \left(\sum_{i=0}^{n} X_i\right) \sum_{i=1}^{n} \left(M_i \times Y_i \times \partial Z_i\right) + \left(\sum_{i=0}^{n} X_i\right) \sum_{i=1}^{n} \left(M_i \times Z_i \times \partial Y_i\right) + \left(\sum_{i=0}^{n} X_i\right) \sum_{i=1}^{n} \left(Z_i \times Y_i \times \partial M_i\right) \quad (13)$$

The change in income resulting from a change in the cropped area, productivity, product prices, and diversification is estimated from the Equation (13). Equation (13) represents the variation in income resulting from a change in the total cropped area (term 1), the prices of agricultural commodities (term 2), agricultural yields or technological innovation (term 3) and land reallocation among crops (term 4). When the term $\left(\sum_{i=0}^{n} X_i\right) \sum_{i=1}^{n} \left(Z_i \times Y_i \times \partial M_i\right)$ becomes positive it indicates a shift of land from lower value crops to higher value crops. The Equation (13) offers the total contributions of various sources to the change in revenue and also the proportional contributions of individual components.

3. Results and Discussion

3.1 Cropping Pattern

Figure 1 depicts the share of cereals, citrus, fiber crops, fruit crops, oilseeds, pulses, root crops, sugar crops, tree nuts, and vegetables produced in Bangladesh, Bhutan, India, Pakistan, Nepal, Sri Lanka, Maldives, and Afghanistan from 1991 to 2020. Even though the share of cereals has decreased in most countries, cereals will continue to dominate South Asian agriculture in 2020. The area share under cereals ranges from 78 percent (Bangladesh) to 1.80 percent (Maldives). In India, the area under cereals decreased from 57.08 percent in 1991 to 45.13 percent in 2020, which was primarily replaced by fiber crops, fruits, oilseeds, pulses, and sugar crops, the share of these crops increased by 3.20, 1.92, 2.38, 1.57, and 0.48 percent, respectively, in 2020. Over the last three decades, there have been significant changes in the country's oilseeds scenario, which is clearly reflected in Fig. 1 [20]. In 1991, oilseeds covered more than half of the agricultural land in the Maldives, but by 2020, oilseeds had been replaced by vegetables.

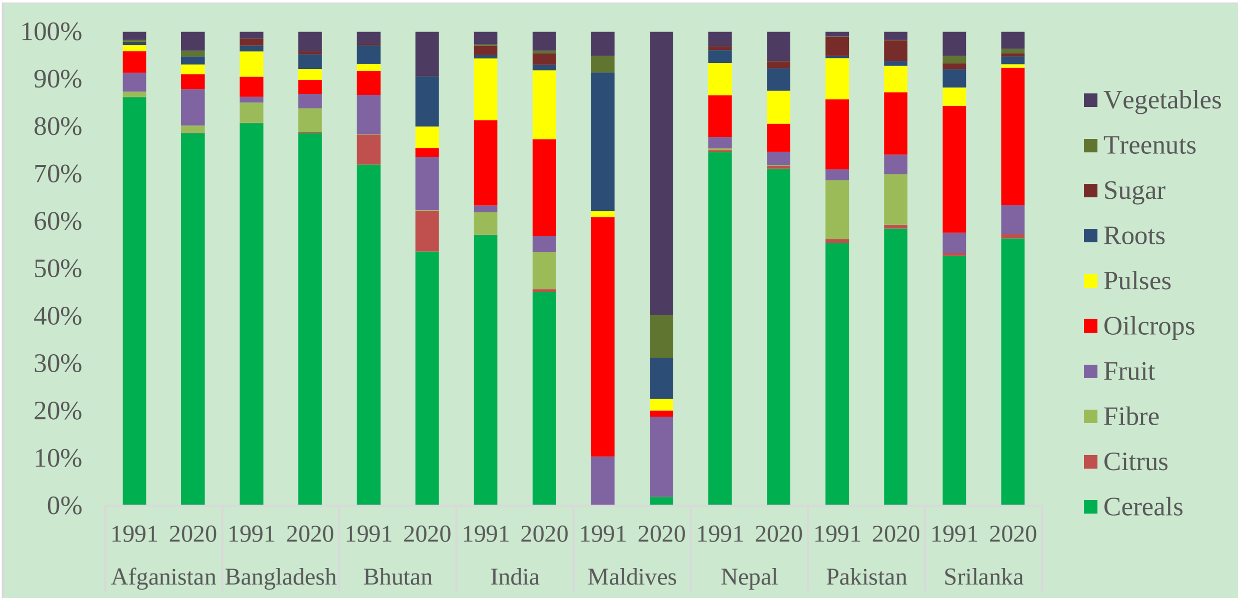


Figure 1. Share of different crops (%)

3.2 Dynamics of Cropping Pattern

Table 2 shows the percentage changes in the cropping pattern over three decades, namely Period I (1991-2000), Period II (2001-2010), Period III (2011-2020), and Period IV (1991-2020) representing the entire time span for the eight South Asian countries. In 2020, the area under root crops increased by 329.07 % over the base year of 1991 in Afghanistan, followed by tree nuts (224.44%), vegetables (205.45%), fruit (152.08%), and pulses (100.55%). In contrast, the sugar crops and oilseeds cultivation decreased by 29.09 and 12.26 percent, respectively. Citrus, fruits, and vegetables reported remarkable growth in Bangladesh, with 337.97, 178.75, and 224.30 percent, respectively. Except for vegetables, pulses, and roots crops, the area under all crops, including cereals, fruits, citrus, oilseeds, fiber, and sugar crops, has decreased over time in Bhutan. Crop diversification toward high-value crops can enhance farm revenue, and the demand for high-value food items is expanding more rapidly than the demand for staple crops [21]. Table 1 also reveals that the area under cereals has decreased throughout all decades and the entire study period and has been primarily replaced by fruit and citrus cultivation in India. A similar scenario was observed in the Maldives, where the area under oilseeds was replaced by vegetables and increased by 861.13%. The area under major cereals and oilseeds in Nepal has decreased over time, but it is increasing for high-value crops like vegetables (138.91%), tree nuts (204.17%), roots (103.40%), and fruits (39.91%) [22]. In Pakistan, the area under roots, fruit, and vegetables increased by 131.99, 101.23, and 95.04 percent over the entire period.

Table 1. Change in cropping pattern in South Asian (%)

Country		Cereals	Citrus	Fiber	Fruit	Oilseeds	Pulses	Roots	Sugar	Tree nuts	Vegetables
AUG	I	12.42	9.42	114.29	9.92	3.98	33.66	5.26	-31.25	-4.58	107.35
	II	32.67	-51.94	-34.00	47.80	-26.61	15.02	54.29	90.00	28.61	6.75
	III	-10.81	263.67	49.61	56.67	26.17	-6.40	178.37	-46.86	126.45	48.88
	IV	17.26	90.24	76.33	152.08	-12.26	100.55	329.07	-29.09	224.44	205.45
BGD	I	4.85	39.69	-26.82	11.20	-10.68	-25.39	69.67	-4.65	-	51.80
	II	2.04	129.04	-7.49	138.77	-8.31	-52.55	50.20	-23.02	-	56.09

	III	1.72	18.63	80.28	2.08	11.58	45.29	5.44	-30.44	-	37.03
	IV	10.43	337.97	34.61	178.75	-20.31	-51.77	191.42	-54.74	-	224.30
BTN	I	5.89	6.50	-10.31	10.31	-36.03	-15.32	8.06	0.24	-	35.81
	II	-10.41	-8.04	1.14	17.85	-50.37	19.72	32.22	4.87	-	73.01
	III	-46.18	-40.34	-18.27	-50.08	-39.61	38.50	5.07	-97.02	-	-19.76
	IV	-66.75	-39.88	-12.37	-39.52	-83.66	38.86	17.68	-96.83	-	68.99
IND	I	-0.43	76.98	14.24	47.72	9.50	-6.46	23.85	17.91	32.55	13.66
	II	-5.11	105.14	17.18	62.02	12.50	7.77	33.03	4.64	28.99	24.31
	III	-4.83	7.20	39.72	9.06	10.31	16.19	11.89	21.24	15.85	18.00
	IV	-7.11	399.07	96.54	174.64	33.04	31.65	82.71	47.17	98.93	78.75
MDV	I	-	-	-	-28.69	-21.74	15.38	-39.39	-	71.63	-28.24
	II	-	-	-	22.00	-62.50	11.70	-50.33	-	35.31	638.91
	III	-	-	-	48.55	-93.60	7.41	-17.99	-	-0.23	95.61
	IV	-	-	-	33.93	-97.87	48.72	-75.62	-	108.65	861.13
NPL	I	8.03	-11.33	-10.77	-12.60	16.67	2.74	23.21	71.09	34.03	14.41
	II	2.93	31.33	-25.29	40.32	-3.48	-0.57	48.69	-0.04	24.20	54.18
	III	1.21	24.06	-45.28	5.55	-32.93	15.66	5.29	17.42	68.20	20.72
	IV	12.79	60.33	-50.10	39.91	-19.95	20.74	103.40	127.38	204.17	138.91
PAK	I	5.49	14.08	11.89	32.94	15.40	-9.94	37.15	34.05	63.24	44.60
	II	7.94	0.67	6.02	35.77	8.04	1.89	28.41	1.56	-14.78	17.17
	III	4.28	1.55	-6.06	-9.12	-5.29	-14.85	36.39	10.39	-13.20	12.26
	IV	17.18	16.26	-5.30	101.23	-0.81	-28.46	131.99	20.29	18.27	95.04
LKA	I	4.23	27.43	-	44.05	4.98	-55.65	-36.43	-11.95	-18.46	-3.34
	II	15.19	42.92	-	2.32	-10.04	-22.79	-17.93	-23.42	-5.29	-0.02
	III	-9.20	0.71	-	-2.09	22.78	-40.68	-11.70	-12.73	-26.21	-14.28
	IV	17.41	107.66	-	53.27	19.19	-80.49	-53.44	-38.29	-35.55	-21.86

Note: Period I-1991-2000, Period II-2001-2010, Period III-2011-2020, and Period IV-1991-2020; AUG- Afghanistan, BGD-Bangladesh, BTN- Bhutan, IND- India, MDV- Maldives, NPL- Nepal, PAK- Pakistan and LKA- Sri Lanka

3.4 Growth of Cropping Pattern

The compound annual growth rate (CAGR) in the cropping pattern over three decades, namely Period I (1991-2000), Period II (2001-2010), Period III (2011-2020), and Period IV (1991-2020) is shown in Table 3. The area under citrus, fiber, fruits, oilseeds, pulses, roots, roots, and vegetables increased significantly in Afghanistan over the entire period (1991-2020), with annual growth rates of 1.3, 1.6, 3.3, 3, 2.7, 3.7, 3.6, and 1.2 percent, respectively. Cultivation of cereals, citrus, fiber, fruits, roots, and vegetables increased significantly in Bangladesh from 1991 to 2020, while cultivation of oilseeds, pulses, and sugar crops decreased significantly.

Table 2. Growth rates of copping pattern

Country		Cereals	Citrus	Fiber	Fruits	Oilseeds	Pulses	Roots	Sugar	Roots	Vegetables
AUG	I	1.9**	0.8	4.2	1.2***	-0.7	4.6**	0.6***	-2.0	-0.2	4.5**
	II	3.6***	-10.5***	-4.6*	4.5***	3.5***	0.8	5.0***	12.3***	4.2***	1.2
	III	3.4**	13.8***	3.6**	7.5***	5.2**	2.0	9.6***	-12.1***	7.9***	4.9**
	IV	0.4	1.3*	1.6***	3.3***	3.0***	2.7***	3.7***	1.0	3.6***	1.2***
B(	I	0.4	4.7***	-2.5**	1.3***	-0.6*	2.2***	3.0*	-0.8***	-	3.1***

	II	0.1	9.7***	0.7	12.1***	-1.2***	-9.0***	5.7***	-2.6***	-	6.3***
	III	0.2	2.1*	3.6**	-0.8	2.3***	4.7***	0.9**	-3.7***	-	3.6***
	IV	0.5***	5.9***	1.1**	4.3***	-0.8***	-3.7***	4.7***	-2.6***	-	4.3***
BTN	I	1.4**	-2.6	-0.4	-1.0	-4.9***	-0.4	-1.5	0.001	-	-0.5
	II	0.6	-1.3	1.0	3.6*	-3.0	3.6*	4.3***	0.5***	-	8.7***
	III	-6.1***	-8.4***	-0.7	-10.9***	-3.9	2.2**	-0.8	-56.4***	-	-5.1*
	IV	-3.3***	-1.1**	-0.2	-0.9	-6.5***	1.5***	-0.8***	-11.7***	-	1.8***
IND	I	0.02	8.3***	2.3***	3.9***	1.1***	-0.7**	2.0***	1.8**	3.4***	1.8**
	II	-0.02	9.2***	1.7**	6.0***	2.3***	1.8**	4.0***	1.2	2.8***	2.0**
	III	-0.04**	2.2*	1.7	0.7	0.2	2.8***	1.5***	0.5	1.1**	1.7***
	IV	-0.08**	6.2***	1.7***	3.6***	7.0***	1.2***	2.3***	1.2***	2.5***	2.5***
MDV	I	31.8***	-	-	-2.3	-1.1	2.3***	-5.2***	-	7.7***	-3.0***
	II	-0.6	-	-	6.9**	-27.8***	2.3	-9.2***	-	4.9***	13.9*
	III	2.3***	-	-	3.9	29.7***	0.6**	-2.5***	-	0.1	11.2***
	IV	8.5***	-	-	-1.2*	-14.7***	1.7***	-5.4***	-	2.6***	9.9***
NPL	I	1.3***	-3.6*	-1.2	-3.3**	1.9***	0.4	2.5***	5.6***	3.2***	1.7**
	II	0.4***	1.9	-1.8*	3.2***	-0.2	0.3	3.5***	0.5	2.3***	4.8***
	III	-0.02	2.0***	-6.3***	0.3	-4.9**	1.7***	0.7**	2.5***	3.8***	2.0***
	IV	0.5***	2.1***	-2.0***	2.8***	-0.08	0.4***	3.0***	2.6***	3.8***	3.3***
PAK	I	0.8***	1.6***	1.1**	3.4***	1.6***	-0.7*	3.7***	2.7***	4.0***	4.1***
	II	1.2***	0.5	0.2	4.1***	0.9*	0.7**	3.6***	0.8	-1.5***	2.6***
	III	0.7**	0.4**	-1.5*	-0.9***	1.7**	1.8***	2.4***	1.8	-1.6***	1.3***
	IV	0.6***	0.3***	-0.3*	2.9***	-0.2	-1.1***	3.3***	0.8***	-0.5**	2.1***
LKA	I	-0.6	2.6***	-	4.3***	0.7***	-10.8***	-4.4***	-1.4	-2.7***	-0.4
	II	2.4*	4.0***	-	0.1	-1.5***	-2.4*	-2.2***	-3.3***	-1.0*	0.9
	III	-1.4	-0.4	-	-0.4	2.2***	-4.6***	-1.6***	1.5	-3.5***	-1.9**
	IV	1.3***	2.9***	-	1.3***	0.2	-5.4***	-2.1***	-1.4***	-0.7***	-0.5***

Note: ***, ** and * indicates significant at 0.01, 0.05 and 0.10 level; Note: Period I-1991-2000, Period II-2001-2010, Period III-2011-2020 and Period IV-1991-2020; AUG- Afghanistan, BGD- Bangladesh, BTN- Bhutan, IND- India, MDV-Maldives, NPL- Nepal, PAK- Pakistan and LKA- Sri Lanka

The CAGR of all agricultural crops in Bhutan was negative, with the exception of pulse crops, which increased by 1.5%per year. In India, the area under cereals has been replaced by high-value crops, and it can be seen from Table 3 that, aside from cereals, the area under high-value crops has increased significantly. The vegetable and cereal cultivation has increased by 9.9 and 8.5 percent, respectively, while the area under oilseed crops has decreased by 14.7% per year in the Maldives. In Nepal, annual growth rates for cereals, citrus, fruits, pulses, roots, and vegetables were 0.5, 2.1, 2.8, 0.4, 3.0, and 3.3 percent, respectively. The cultivation of cereals, citrus fruits, roots, sugar crops, and vegetables increased significantly in Pakistan, but only cereals, citrus fruits, and oilseeds increased significantly in Sri Lanka.

3.5 Panel data unit root testing

Before analyzing the determinants of crop diversification, it is necessary to determine whether the determinants are free of unit-roots. We use the Levin-Lin-Chu and Im-Pesaran-Shin root tests to assess stationarity in a 30-year panel data set. The majority of the determinants (arable land ha/person, cropland percent, population, merchandise index, temperature (maximum and minimum), rainfall, food crop yield index, and non-food crop yield index), according to the Levin-Lin-Chu test, were stationary at the level, while the rest became the stationary first difference. The Im-Pesaran-Shin test gives quite similar results in which cropland percent (share), merchandise index, temperature (maximum & minimum), root zone moisture, rainfall, fertilizer, pesticide, food crop yield index, and non-food crop yield index were stationary at a level. At the same time, other determinants such as arable land ha/person, per capita gross domestic product, and the population became the stationary first difference.

Table 3. Stationarity testing

Particulars	Levin-Lin-Chu test	Im-Pesaran-Shin test
Entropy diversification Index	First difference **	At level*
Arable land ha/person	At level**	First difference **
Per capita GDP (USD)	First difference **	First difference **
Cropland percent (share)	At level**	At level**
Population ('000 person)	At level**	Second difference **
Merchandize index	At level**	At level**
Temperature (maximum)	At level**	At level**
Temperature (minimum)	At level**	At level**
Root zone moisture	First difference **	At level**
Rainfall (mm)	At level*	At level**
Fertilizer (kg/ha)	Second difference **	At level*
Pesticide (kg/ha)	Second difference *	First difference **
Food crop yield index	At level*	At level**
Non-food crop yield index	At level*	At level**

Note: ***, ** and * indicates significant at 0.01 and 0.05 level

3.6. Model Specification

In a regression model, the Hausman specification test finds endogenous repressors (predictor variables). It is also called a model misspecification test. In panel data analysis, the Hausman test permits the selection of a fixed-effects model (FEM) or a random-effects model (REM), and the findings are provided in Table 4. On the basis of test findings, a random effect model was selected.

Table 4. Hausman test

Hypothesis	Hausman test	Test statistics	p value	Model selection
H_o = FEM H_1= REM	χ^2	7.16	0.519	Random effect model

3.7 Determinants of Crop Diversification

The results of the Random effect model using panel data regression are shown in Table 5. The estimated R-square was 0.69, implying that all of the determinants listed in Table 5 together explained 69 percent of the total variations in the crop diversification index. The results show that per capita gross domestic product (USD), temperature (minimum), pesticide, food crop yield index, and non-food crop yield index have a statistically positive and significant impact on crop diversification in South Asian agriculture throughout the study period.

Table 5: Estimates of random effect model

Particulars	Model- Entropy Diversification Index

	Coefficient
Arable Land ha/person	-0.054 (0.108)
GDP per capita USD	0.00005*** (~0)
Crop land per cent (Share)	-0.049*** (0.009)
Population ('000 person)	-0.000004*** (~0)
Merchandise index	-0.039 (0.074)
Temperature (Maximum)	0.0006 (0.002)
Temperature (Minimum)	0.003*** (0.001)
Root zone moisture	-0.055 (0.055)
Rainfall (mm)	0.000002 (~0)
Fertilizer (kg/ha)	0.00003 (~0)
Pesticide (kg/ha)	0.0005*** (0.0001)
Food crop yield index	0.0004*** (0.0001)
Non-food crop yield index	0.0005** (0.0003)
Bangladesh	0.759*** (0.162)
Bhutan	0.017 (0.033)
India	0.985*** (0.116)
Maldives	0.313*** (0.074)
Nepal	0.144*** (0.029)
Pakistan	0.732*** (0.084)
Sri Lanka	0.441*** (0.075)
Intercept	0.472*** (0.100)
σe	0.0369
Overall R^2	0.69

Note: Indicates *** and ** significant at 0.01 and 0.05 level; Figure in parenthesis are robust standard error of the respective coefficient.

On the other hand, cropland percent (share) and population have a significant negative impact on crop diversification. The effect of maximum temperature, rainfall, and fertilizer on the Entropy diversification index was positive but not statistically significant. Increases in all determinants have a significant and positive impact in Bangladesh, India, Maldives, Nepal, Pakistan, and Sri Lanka, leading to crop diversification within these countries, but have a significant negative impact in Bhutan, where crop diversification increases but not significantly. The current status of crop diversification and its various determinants are presented in Figure 2. The figure also shows that Afghanistan and Bangladesh have the most diverse agriculture, followed by Nepal, Pakistan, Bhutan, and Indian agriculture being more specialized. Afghanistan, the most diverse country, has the highest fertilizer consumption and rainfall, which do not affect diversification. The area under food crops has a significant impact on crop diversification, as evidenced by the extent of crop diversification and the food crop yield index in Afghanistan (Table 5 and Figure 6). Bangladesh and Sri Lanka use the most pesticides, followed by Pakistan and India, with Nepal and Bhutan using the least.

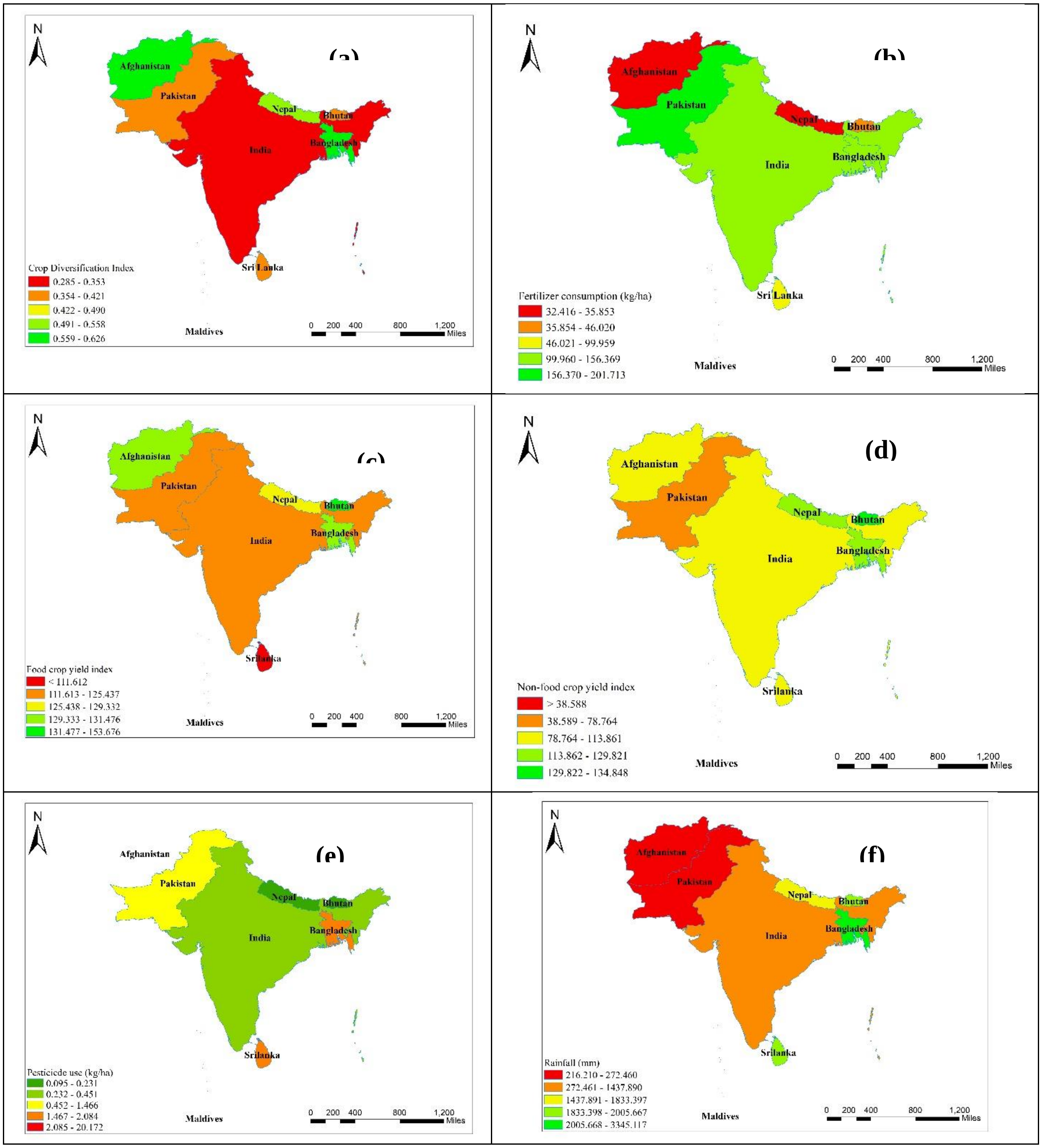


Figure 2. Status of crop diversification and their determinant

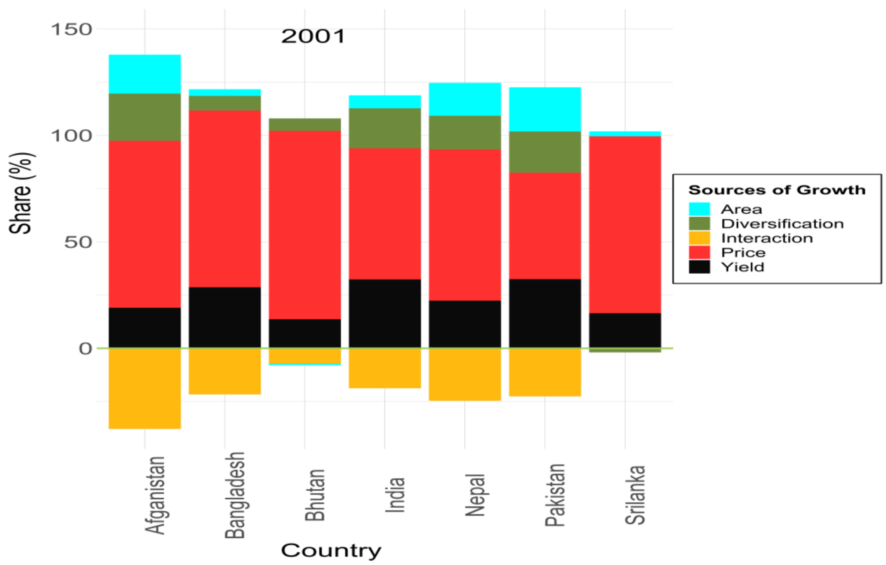
3.8. Sources of Agriculture Growth

Table 6 shows the decomposition of agricultural growth into area effect, yield effect, price effect, and diversification over three time periods: 2001, 2011, and 2020 as visualized in Figure 3. A clear understanding of the drivers of agricultural growth is essential to assess the current trends in sustainability and identify future policy priorities.

Table: 6 Share of various sources to income growth during 2001-2020 (%)

Country	Year	Area	Yield	Price	Diversification	Interaction
Afghanistan	2001	18.29	19.04	78.44	22.13	-37.91
	2011	16.61	32.10	82.37	6.96	-38.04
	2020	-32.72	24.60	80.14	24.88	3.11
Bangladesh	2001	3.16	28.64	83.01	6.87	-21.68
	2011	6.29	30.14	83.52	7.14	-27.09
	2020	13.00	25.76	81.59	-6.59	-13.76
Bhutan	2001	-0.72	13.63	88.51	5.84	-7.25
	2011	-3.82	25.32	85.89	13.79	-21.18
	2020	-23.39	52.75	86.54	-7.35	-8.55
India	2001	6.08	32.36	61.58	18.78	-18.80
	2011	7.82	5.07	88.46	11.56	-12.92
	2020	15.99	30.76	73.72	-5.88	-14.59
Nepal	2001	15.47	22.37	71.00	15.81	-24.65
	2011	9.75	22.93	79.21	15.41	-27.31
	2020	4.12	29.63	73.06	11.48	-18.30
Pakistan	2001	20.80	32.45	50.01	19.34	-22.59
	2011	7.09	11.66	92.01	1.16	-11.93
	2020	-4.59	30.93	74.85	14.67	-15.87
Sri Lanka	2001	2.33	16.46	83.11	-1.67	-0.23
	2011	15.63	16.90	91.55	-13.52	-10.55
	2020	-3.76	-4.18	100.56	-0.02	7.41

Output prices contributed more than half of agricultural growth and remained the primary source of growth in all South Asian countries. The yield was identified as the second important factor. In the year 2020, agricultural crop yields contributed 24.60, 25.76, 52.75, 30.76, 29.63, and 30.93% in Afghanistan, Bangladesh, Bhutan, India, Nepal, and Pakistan, respectively. The contribution of crop diversification to agricultural growth has been decreasing over time, but in Afghanistan, Nepal, and Pakistan, it contributed 24.88 percent, 11.48 percent, and 14.67 percent, respectively, in 2020.



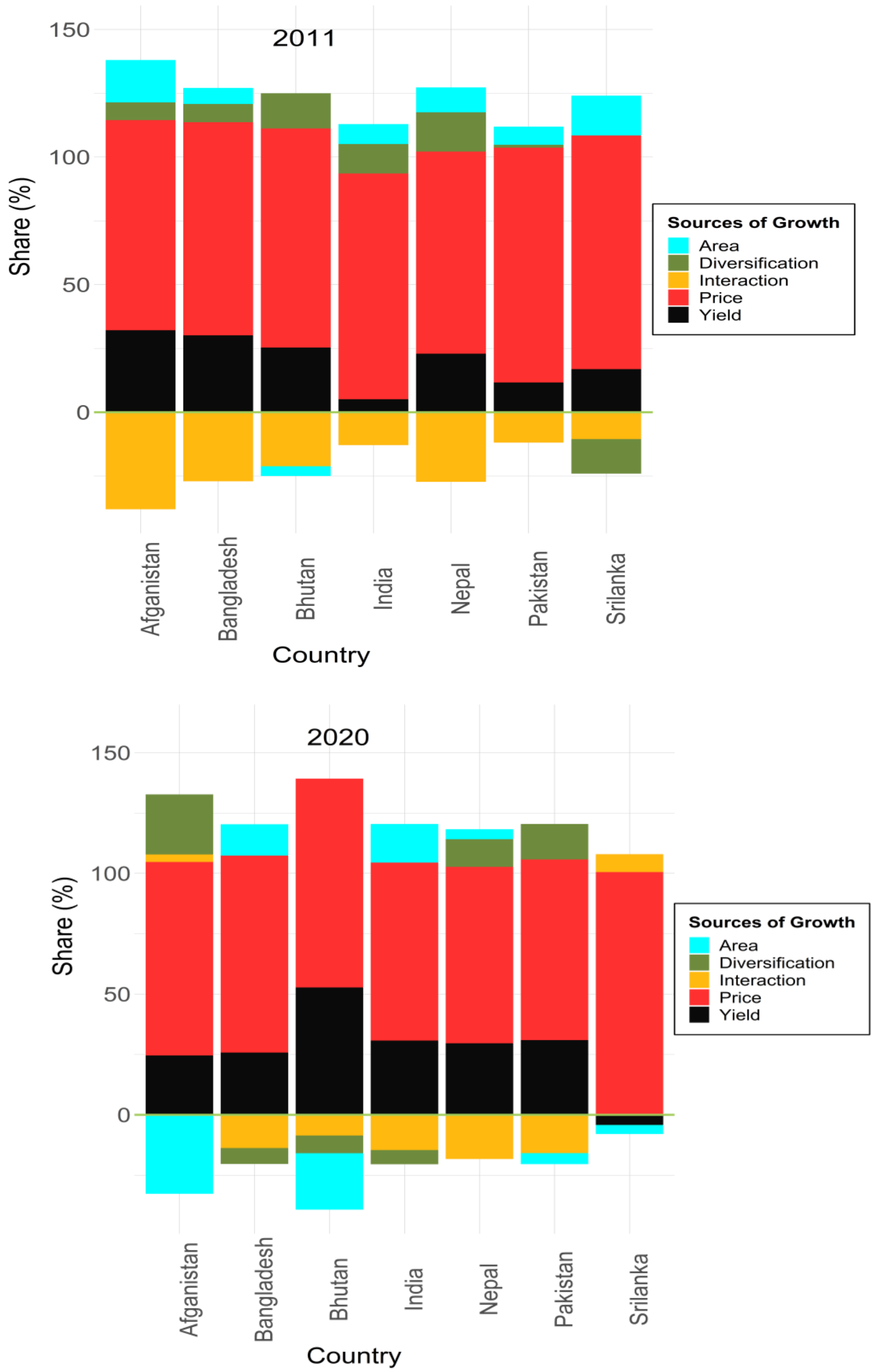


Figure 3. Source of growth (2001, 2011, and 2020)

5. Conclusions

This study investigated crop diversification status and various determinants in eight South Asian countries, considering socioeconomic, soil/agronomic, agricultural inputs, the productivity of food and non-food crops, international trade, and climate factors. Although the share of cereals has decreased in most countries, cereals will continue to dominate South Asian agriculture in 2020. The area under high-value crops in India has increased significantly, replacing the area under cereal cultivation during the study period. Similar results were observed in the Maldives, where vegetables replaced the area under oilseeds. The Hausman model specification test in panel data analysis recommends a fixed-effects model or a random-effects model. The estimated R-square was 0.69 percent, indicating that all determinants explained 69 percent of the total variations in the crop diversification index. The crop diversification in south Asia was influenced by per capita GDP, minimum temperature, pesticide consumption, food crop yield index, and non-food crop yield index during the study period. Cropland percentage and population, on the other hand, both harm crop diversification. The maximum temperature, rainfall, and fertilizer have a statistically insignificant effect on the Entropy index of diversification. All the determinants have a significant and positive impact in Bangladesh, India, the Maldives, Nepal, Pakistan, and Sri Lanka, leading to crop diversification within these countries but negatively impacting Bhutan, where crop diversification increases in a not significant manner. Afghanistan and Bangladesh have the most diverse agriculture, followed by Nepal, Pakistan, Bhutan, and Indian agriculture, which is more specialized. The most diverse country, Afghanistan, has the highest fertilizer consumption and rainfall, neither of which affects diversification. In 2020, the price factor contributes more than half to agricultural growth. It remains the primary source of growth in all South Asian countries, with yield being identified as the second most important factor. The contribution of crop diversification to agricultural growth has been declining over time. As such mono-cropping gives rise to insect-pest which evolve over time and hard to manage, however when there is diversification same insect pest do not get chance to develop resistance. It has been proved that diverse cropping improves soil quality through nutrient recharge and improving soil micro biota, hence is essential for sustainable agriculture. Thus, crop diversification can be a novel option to improve agricultural input productivity, management of degraded soil, and system productivity to achieve food and nutritional security through sustainable agriculture.

Author Contributions:

Conceptualization, P.S., P.A., A.G., P.B.B., A.K.B., M.B. and P.B.; Data curation, P.S.; Formal analysis, P.S., P.A., A.G., P.B.B. and A.K.B.; Funding acquisition, P.B.; Investigation, P.A., A.G., P.B.B., and M.B.; Methodology, P.S., P.A., A.G., P.B.B., A.K.B., M.B. and P.B.; Project administration, A.K.B.; Resources, M.B.; Supervision, A.K.B. and P.B.; Validation, P.B.B.; Visualization, P.S., P.A., A.G. and P.B.B.; Writing—original draft, P.S., P.A., A.G. and P.B.B.; Writing—review and editing, A.K.B., M.B. and P.B. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest:

The authors declare no conflict of interest

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Annexure I Specification of variables and their expected signs for diversification

Factors	Indicators	Unit	Expected sign
Socioeconomic	Per capita GDP	USD	+
	Population	'000 person	-
	Arable land	ha/person	+
	Cropland	Percentage	-
Soil/agronomic	Root zone moisture	Per cent	+
Agricultural inputs	Fertilizer	kg/ha	+
	Pesticide	kg/ha	+
Productivity	Food crop yield index	Per cent	+
	Non-food crop yield index	Per cent	+
International trade	Merchandize index		+
Climate	Temperature (Maximum)	ºC	+
	Temperature (Minimum)	ºC	+
	Rainfall (mm)	Millimeter	-