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Impact of Livelihood Sustainability, Regional Variability and Pathways to Sustainable Development: Evidence from Haryana, North India

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ABSTRACT

Measuring sustainability using economic, ecological, and social indicators is crucial for achieving sustainable development goals. This paper focuses on livelihood sustainability in the state of Haryana, with a diverse mixture of urban and rural areas, where agricultural activities play a dominant role in the economy. The research assessed the economic, ecological and social factors that influence sustainability across various districts of Haryana, identifying disparities and highlighting the challenges faced by different regions. Data were collected from secondary sources, such as government reports on economic, agricultural, and social indicators. The study utilises the sustainability index approach, path analysis and regression models to examine the relationships between sustainability indicators and overall livelihood sustainability. The findings indicated that urban areas, such as Gurgaon, perform well in terms of economic sustainability, thanks to their industrial growth and infrastructure development. In contrast, rural districts such as Nuh and Palwal face significant challenges, including low income, poor infrastructure, and limited access to essential services. The study also highlights the environmental issues that impact sustainability, including water scarcity and soil degradation. The results revealed the need for targeted interventions to address these regional disparities and promote a more sustainable future for Haryana's diverse districts.

Keywords: Livelihood sustainability, sustainable development, path analysis, regional disparities, Haryana

JEL codes: Q01, Q15, Q56, Q18, R11

I

INTRODUCTION

Sustainable livelihoods are essential for ensuring that farm communities can meet their needs without compromising the ability of future generations to do the same, which involves maintaining a balance between economic stability, environmental health, and social well-being (Rachman et al., 2022). In rural areas, where the majority of the population relies on agriculture and its associated activities, the sustainability of their livelihoods is influenced by several key factors, including farming practices, climate conditions, and access to social services (Kareemulla et al., 2017). The way in which communities manage resources and adapt to environmental changes directly impacts their long-term viability. Additionally, rural areas often face significant challenges related to limited access to modern technology, financial services and healthcare. In recent years, the focus on sustainable development has intensified, particularly in rural regions, as their challenges related to climate change, economic inequality, and resource depletion have become more evident (Parmaksız et al., 2024). Haryana is renowned for its substantial agricultural output and rapid industrial growth; however, it faces varying levels of sustainability across its districts.

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While some regions have seen impressive development in terms of economic growth and infrastructure, others are grappling with challenges that threaten long-term sustainability. Haryana's diverse landscape, ranging from industrial hubs to rural villages, provides a unique setting (Kumar and Kumar, 2020) for understanding how regional disparities influence overall sustainability. The state encompasses both urban areas, such as Gurgaon, which has experienced considerable economic growth, advanced infrastructure, and a booming service sector, as well as rural districts, including Nuh, where persistent developmental challenges persist. While certain areas in Haryana benefit from strong infrastructure, higher income levels, and improved access to healthcare and education, other districts struggle with issues such as inadequate financial access, low agricultural productivity, and poor social infrastructure (Singh & Hiremath, 2010). These discrepancies highlight the need for targeted development strategies that can address specific regional needs. Furthermore, environmental factors such as water scarcity, soil degradation, and irregular rainfall patterns add further complexity to achieving sustainability. These challenges are compounded by the effects of climate change, which threatens to disrupt agricultural cycles and exacerbate the vulnerability of rural communities. Therefore, the present study aims to examine these differences by assessing how economic, ecological, and social factors interact to affect livelihood sustainability in different districts of Haryana, using a combination of path analysis and regression models to investigate the impact of selected sustainability indicators. Understanding how these factors interact within the state's districts is crucial for developing strategies that promote sustainability across all dimensions. This study not only aims to assess the current status of livelihood sustainability in Haryana but also provides a framework for future interventions that can enhance the resilience of its rural communities and ensure their continued well-being in the face of emerging challenges.

II

METHODOLOGY

Haryana is a northern state of India, located between 74°27′E to 77°36′E longitudes and 27°39′N to 30°35′N latitudes. The state comprises 22 districts, encompassing both urban and rural landscapes. Secondary data related to various sustainability-related indicators across these districts were obtained from official publications of the Directorate of Economics and Statistics and the Department of Agriculture, Government of Haryana, India. Livelihood Sustainability of different districts were assessed based on the three dimensions, i.e., Economic sustainability, Ecological sustainability and Social sustainability. Each of the dimensions was studied through the measurement of different indicators (Table 1). The selection of indicators under each dimension was based on the ability to measure each dimension and the extent to which the dimensions influence the level of indicators.

TABLE 1. SELECTED INDICATORS FOR LIVELIHOOD SUSTAINABILITY ASSESSMENT AND ITS MEASUREMENT

Code	Particulars	Unit	Type of indicator	Year
	Economic Sustainability Indicators			
EE1	Quantity of pesticides consumed in agriculture	Tonnes	Negative (-)	2023-24
EE2	Milk produced per unit of livestock	Kgs	Positive (+)	2023-24
EE3	Number of households served by each bank in the region	Nos.	Negative (-)	2023-24
EE4	Per capita income at current prices	Rs/annum	Positive (+)	2023-24
EE5	The total amount of rainfall received in a year	MM	Positive (+)	2023-24
	Ecological Sustainability Indicators			
ES1	Cropping intensity: Ratio of cropped area to net sown area.	%	Positive (+)	2023-24
ES2	Livestock density: Number of livestock per unit of land	no./sq.km	Negative (-)	2023-24
ES3	Total land area covered by forests in the region	Sq. Km.	Positive (+)	2023-24
ES4	Total area of land under cultivation for crops	1000 ha.	Positive (+)	2023-24
ES5	Variation in annual rainfall from the average rainfall pattern over a period	C.V	Negative (-)	2023-24
ES6	Groundwater development stress	Draft (%)	Negative (-)	2023-24
ES7	The level of pressure on groundwater resources due to their extraction and usage	Depth (m)	Positive (+)	2023-24
	Social Sustainability Indicators			
SE1	Infant death /mortality: Rate of infant deaths per 1,000 live births	Nos.	Negative (-)	2023-24
SE2	Total length of roads in kilometres	Km	Positive (+)	2023-24
SE3	Number of electricity connections for agriculture	Nos.	Positive (+)	2023-24
SE4	Number of Primary Agricultural Credit Societies for farmers	Nos.	Positive (+)	2023-24
SE5	No. of officially Govt. recognised schools	Nos.	Positive (+)	2023-24
SE6	Teacher Pupil Ratio: Students per teacher in primary schools	%	Negative (-)	2023-24

2.1 Evaluation of Livelihood Sustainability Index

The individual sustainability indices (EEI, ESI, and SEI) for each of the three dimensions were constructed based on the Human Development Index (HDI) developed by the UNDP (1990). To organise the collected data for each sustainability dimension, a structured rectangular matrix was formulated, where rows denoted the districts and columns symbolised the respective indicators. Considering the existence of L districts (j = 1, 2, …, L) and the collection of K indicators (i = 1, 2, …, K), the resulting table comprised L rows and K columns. Represented as x_{ij}, the value of the i_{th} indicator for the j_{th} district was specified.

$$Z_{ij} = \frac{x_{ij} - \text{Min}\{x_{ij}\}}{\text{Max}\{x_{ij}\} - \text{Min}\{x_{ij}\}} \quad \text{(Positive relationship) -------------- (i)}$$

$$Z_{ij} = \frac{\text{Min}\{x_{ij}\} - x_{ij}}{\text{Max}\{x_{ij}\} - \text{Min}\{x_{ij}\}} \quad \text{(Negative relationship) ------------- (ii)}$$

Where Min$\{x_{ij}\}$and Max$\{x_{ij}\}$ are the minimum and maximum values of i^{th} indicator among all the L districts, respectively

$$ESI_j = \sum_1^i (w_i \times Z_{ij}) \quad \text{-------------- (iii)}$$

where $\sum_1^i w_i = 1$where ESI_j represents the ESI for the j^{th} district and w_i denotes the weight associated with the i_{th} indicator included for the computation of ESI.

For estimating the weight associated with the indicator (Iyengar and Sudarshan, 1982)

$$w_i = \frac{c}{\sqrt{Var\ (Z_{ij})}} \quad \text{-------------- (iv)}$$

Where C is a standardised constant such that

$$C = \sum_{j=1}^k \frac{1}{\sqrt{var(Z_{ij})}} \quad \text{-------------- (v)}$$

Therefore, the Sustainable Livelihood Security Index (SLSI) was computed as follows.

$$SLSI_j = W_{ESI} * ESI_j + W_{EEI} * EEI_j + W_{SEI} * SEI_j \quad \text{-------------- (vi)}$$

The overall livelihood sustainability of the districts was assessed by constructing a composite SLSI, which was calculated by averaging the three sustainability indices. Based on the values of the sustainability indices, the districts were categorised into four groups: less sustainable ($0.00 \leq x \leq 0.25$), moderately sustainable ($0.26 \leq x \leq 0.50$), sustainable ($0.51 \leq x \leq 0.75$), and highly sustainable ($0.76 \leq x \leq 1.00$).

2.2 Factors Affecting the Livelihood Sustainability

Path analysis is a multivariate statistical technique used to identify the variable that contributes the most to the three dimensions of sustainability. It consists of two paths: the direct path and the indirect path. It specifies the relationship between the observed variables and examines the causal relationship among the variables. It indicates how the variables relate to one another and allows for the development of logical theories about the processes influencing a particular outcome (Duncan, 1966). The steps to estimate the direct and indirect effects are as follows

1) Standardise both effect (Y) and causal variables (Xs) as (x*) = (x-m)/SD, where, x* is the standardised value, x is the original value, m is the mean, and SD is the standard deviation.

2) Regress the effect variable (Y) on the standardised variables (x*), which gives the partial regression coefficients (direct path coefficients).

3) The path coefficient (direct effect) from cause X_1 to the effect Y is given as

$Y = \sigma X_1/\sigma Y_1$, where σ is the standard deviation.

4) The indirect contribution of X_1 to Y includes X_1 through X_2, X_3, *etc.* The same applies to X_2, X_3, *etc.* The equation below shows the splitting process for causal variables with one effect variable, Y.

$$r(X_1, Y) = a + r(X_1, X_2)\, b + r(X_1, X_3)\, c \quad \text{.....vii}$$

$$r(X_2, Y) = r(X_2, X_1)\, a + b + r(X_2, X_3)\, c \quad \text{.....viii}$$

$$r(X_3, Y) = r(X_3, X_1)\, a + r(X_3, X_2)\, b + c \text{.........} \textit{etc.} \quad \text{....xiv}$$

Where, a,b,c are the partial regression coefficients and $r(X_1, X_2)$, $r(X_1, X_3)$,… are the correlation coefficients.

The above equation shows the partition of each of the correlations from (X_1 to Y), (X_2 to Y), *etc,* into their component paths.

i. Due to the direct effect of X_1 on Y
ii. Due to the indirect effect of X_1 on Y via X_2
iii. Due to the indirect effect of X_1 on Y via X_3, *etc.*

If the correlation coefficient between a causal factor and effect is almost equal to the direct effect, then correlation explains the true relationship. If the correlation coefficient is positive but the direct effect is negative, the indirect effect seems to be the cause of the correlation. In such cases, indirect causal factors should be taken into account. The correlation coefficient may be negative, but the direct effect is positive and high. In these circumstances, a method to selectively eliminate the undesirable indirect effects will need to be introduced (Singh and Chaudhary, 1995).

2.3 Impact of Indicators on Livelihood Sustainability

To analyse the impact of selected indicators on livelihood sustainability, Multiple linear regression (MLR) was employed by using the ordinary least squares (OLS) estimation method under the ENTER procedure (Bell and Morse, 2012). Prior to regression, the selected variables were examined for normality, linearity and multicollinearity to ensure compliance with the assumptions of OLS regression. The variance inflation factor (VIF) was used to test for multicollinearity among predictors, while residual plots were inspected to verify homoscedasticity and the normal distribution of errors. A total of six independent variables were selected for analysis, comprising two key indicators from each of the three dimensions of livelihood sustainability: economic, ecological, and social. The dependent variable in this analysis was the overall composite livelihood sustainability

The regression model is expressed in the following functional form:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon$$

Where,

Y is the dependent variable representing livelihood sustainability
α is the intercept or constant term
β_1 to β_6 are the regression coefficients of the respective selected independent variables
X_1 to X_6 are the selected independent variables
ε is the error term capturing the unexplained variation in the model

The model diagnostics involved computing the coefficient of determination (R^2) and the adjusted R^2 to assess the overall fit of the model. The F-statistic was calculated to test the joint significance of the regression coefficients, while the significance of individual predictors was assessed using t-statistics and associated p-values. Standard errors were used to evaluate the precision of the coefficient estimates.

III

RESULTS AND DISCUSSION

The economic sustainability (Table 2) across Haryana's districts varied significantly due to factors such as agricultural practices, financial access and income levels. Gurgaon (EEI = 0.81) performed primarily due to its high milk production (EE2 = 1.00), efficient pesticide consumption (EE1 = 1.00) and excellent access to financial services (EE3 = 1.00). This pattern aligns with Raji et al. (2024), who found that access to modern farming techniques and financial services contributes to higher agricultural productivity and economic growth. On the contrary, districts such as Nuh (EEI = 0.41) and Palwal (EEI = 0.29) exhibit much lower economic sustainability due to low milk production (EE2 = 0.00 for Nuh), limited banking access (EE3 = 0.00 for Nuh) and lower per-capita income (EE4 = 0.34 for Palwal). These disparities underscore the pressing need for enhanced financial inclusion and improved agricultural practices, as research suggests that a lack of access to finance and modern farming techniques significantly hinders socio-economic development in rural areas (Fowowe, 2020). Faridabad (EEI = 0.58) exhibited moderate economic sustainability, characterised by high pesticide consumption (EE1 = 0.96) and moderate per-capita income (EE4 = 0.54), yet it also faced limited environmental challenges, including low rainfall (EE5 = 0.54). Similarly, Karnal (EEI = 0.40), which had minimal pesticide use (EE1 = 0.00), demonstrated a shift toward sustainable farming practices; however, it faced issues such as low milk production (EE2 = 0.75) and inconsistent rainfall (EE5 = 0.94). These challenges further underline the need for improved irrigation practices and crop diversification to manage climate variability and ensure the long-term productivity of agriculture.

The ecological sustainability (Table 2) of Haryana's districts showed considerable variation, reflecting the influence of factors such as land use, livestock density, forest cover and groundwater stress. Panchkula (ESI = 0.60) emerged as the highest performer in terms of ecological sustainability, exhibiting high values across key indicators such as livestock density (ES2 = 1.00) and forest cover (ES3 = 1.00). This aligns with research indicating that better land management and balanced livestock density contribute to sustainability (Kumar et al., 2022). The district's low groundwater stress (ES6 = 0.92) further supports its position, suggesting that it has effective water resource management strategies. In contrast, Faridabad (ESI = 0.27) had the lowest ecological sustainability index, with very low values across most indicators, particularly in the forest area (ES3 = 0.11) and groundwater stress (ES6 = 0.60). These low scores indicated significant environmental challenges, especially in terms of deforestation and over-extraction of groundwater resources, which have long-term implications for agricultural biodiversity (Haqiqi et al., 2023). Similarly, Karnal (ESI = 0.53) and Hisar (ESI = 0.58) exhibited a moderate ecological sustainability status, characterised by moderate forest cover (ES3 = 0.94 for Karnal and 0.78 for Hisar), and varying levels of groundwater stress (ES6 = 0.39 for Karnal and 0.78 for Hisar). These challenges address the point for better management of water resources and enhanced ecological conservation practices to reduce the pressure on natural resources. Districts such as Nuh (ESI = 0.55), Jhajjar (ESI = 0.51), and Rohtak (ESI = 0.52) exhibited moderate ecological sustainability. Nuh reported the highest variation in rainfall (ES5 = 1.00), which creates vulnerability to climate variability, which could affect agricultural productivity and increase dependence on groundwater resources. Districts like Palwal (ESI = 0.43) and Charkhi Dadri (ESI = 0.49) experienced higher pressures on their groundwater resources, characterised by moderate forest cover and low cropping intensity, highlighting the need for sustainable water usage and more efficient land management. Although Gurgaon (ESI = 0.51) is not the top performer, it has demonstrated a balanced ecological sustainability profile, characterised by moderate levels of forest cover (ES3 = 0.16), land under cultivation (ES4 = 0.10), and groundwater stress (ES6 = 0.22). This reflects the importance of balancing urban development with environmental conservation, ensuring that agricultural practices and water usage are sustainable even in more urbanised districts.

The districts with strong social infrastructure will contribute to their high social sustainability index. Ambala (SEI = 0.65) is one of the top performers with high values in critical indicators such as infant mortality (SE1 = 0.76) and teacher-pupil ratio (SE6 = 0.81). In contrast, Faridabad (SEI = 0.25) performed poorly, with very low scores in most indicators, especially in infrastructure such as roads (SE2 = 0.00), agricultural credit societies (SE4 = 0.00), and government-recognised schools (SE5 = 0.02). This suggests significant gaps in essential services, highlighting the need for improvements in social infrastructure to promote better living conditions and socio-economic outcomes (Garmendia et al., 2022). Karnal (SEI = 0.77) had the highest score in electricity connections for agriculture (SE3 = 1.00), indicating excellent access to power and to agricultural credit societies (SE4 = 1.00), which help improve agricultural productivity. However, they faced challenges in terms of infant mortality (SE1 = 0.49). Similarly, Mahendragarh (SEI = 0.57) showed high scores in infant mortality (SE1 = 0.96) and educational infrastructure (SE6 = 0.89), highlighting its strong commitment to healthcare and education, key components of social sustainability (Mehra and Sharma, 2021). Districts like Charkhi Dadri (SEI = 0.41) and Nuh (SEI = 0.26) exhibited the lowest scores. Particularly, Nuh is showing poor performance across several indicators, mainly in terms of healthcare (SE1 = 0.01) and educational services (SE5 = 0.00), which suggests that urgent interventions are needed in such districts to address the lack of basic services, which are crucial for long-term social sustainability (Piscitelli et al., 2023). Sirsa (SEI = 0.74) and Yamunanagar (SEI = 0.62) showed well with relatively balanced scores across the various social sustainability indicators, including infant mortality (SE1 = 0.80 for Sirsa and 0.83 for Yamunanagar), infrastructure (SE2 = 0.89 for Sirsa and 0.77 for Yamunanagar) and educational access (SE5 = 0.83 for Sirsa and 0.99 for Yamunanagar).

The rankings of districts across Economic Sustainability, Ecological Sustainability, Social Sustainability, and Livelihood Sustainability (Table 3) provide a nuanced understanding of regional disparities and strengths in terms of sustainable development within the state of Haryana. Gurgaon excels (Rank I) in Economic Sustainability (EEI = 0.81), primarily due to its thriving industrial base, well-developed infrastructure, and robust economic activities, which significantly contribute to its excellent performance (Sehrawat and Shekhar, 2024). Furthermore, Gurgaon secures the second rank in overall Livelihood Sustainability (SLSI = 0.58) due to its well-established social infrastructure and improved access to essential services, which elevate the quality of life for its residents. Conversely, Palwal ranks the lowest in Economic Sustainability (Rank XXII) with a value of 0.29, largely due to its limited industrialisation and insufficient infrastructure, which hampers its ability to generate sustainable economic opportunities for its population. In Ecological Sustainability, Panchkula emerges as a leader with an ESI value of 0.60 (Rank I), which reflects its commitment to environmental conservation, sustainable

TABLE 2. INDICES OF ECONOMICAL SUSTAINABILITY, ECOLOGICAL SUSTAINABILITY AND SOCIAL SUSTAINABILITY OF LIVELIHOODS IN HARYANA

District	Economical sustainability						Ecological sustainability								Social sustainability						
	EE1	EE2	EE3	EE4	EE5	EEI	ES1	ES2	ES3	ES4	ES5	ES6	ES7	ESI	SE1	SE2	SE3	SE4	SE5	SE6	SEI
Ambala	0.49	0.51	0.81	0.22	0.59	0.52	0.77	0.68	0.07	0.28	0.54	0.61	0.19	0.45	0.76	0.56	0.33	0.75	0.71	0.81	0.65
Bhiwani	0.61	1.00	0.49	0.09	0.00	0.44	0.73	0.89	0.10	0.68	0.42	0.68	0.55	0.58	0.74	0.54	0.37	0.31	0.68	0.74	0.56
Charkhi Dadri	0.82	0.59	0.51	0.08	0.39	0.48	0.86	0.37	0.01	0.18	0.89	0.54	0.59	0.49	1.00	0.31	0.14	0.19	0.00	0.81	0.41
Faridabad	0.96	0.29	0.69	0.41	0.54	0.58	0.00	0.00	0.11	0.11	0.67	0.60	0.36	0.27	0.55	0.00	0.05	0.00	0.02	0.85	0.25
Fatehabad	0.77	0.56	0.64	0.12	0.55	0.53	0.67	0.72	0.08	0.54	0.78	0.38	0.57	0.53	0.84	0.65	0.53	0.30	0.45	0.74	0.59
Gurgaon	1.00	0.34	1.00	1.00	0.72	0.81	1.00	0.58	0.16	0.10	0.95	0.22	0.59	0.51	0.32	0.18	0.21	0.06	0.36	1.00	0.36
Hisar	0.09	0.66	0.61	0.10	0.42	0.37	0.72	0.58	0.10	0.85	0.94	0.78	0.09	0.58	0.00	1.00	0.20	0.49	0.92	0.85	0.58
Jhajjar	0.89	0.52	0.68	0.17	0.64	0.58	0.85	0.70	0.04	0.30	0.63	1.00	0.02	0.51	0.93	0.52	0.10	0.20	0.28	0.78	0.47
Jind	0.63	0.54	0.47	0.11	0.49	0.45	0.81	0.23	0.11	0.49	0.97	0.67	0.27	0.51	0.75	0.56	0.58	0.30	0.66	0.70	0.59
Kaithal	0.39	0.55	0.61	0.14	0.18	0.37	0.66	0.52	0.12	0.49	0.08	0.19	0.63	0.38	0.83	0.53	0.77	0.38	0.41	0.81	0.63
Karnal	0.00	0.57	0.75	0.16	0.53	0.40	0.67	0.66	0.14	0.49	0.94	0.39	0.39	0.53	0.49	0.66	1.00	1.00	0.73	0.74	0.77
Kurukshetra	0.52	0.58	0.80	0.19	0.43	0.50	0.75	0.50	0.05	0.34	0.71	0.00	0.83	0.45	0.82	0.37	0.54	0.80	0.74	0.81	0.68
Mahendragarh	0.94	0.35	0.53	0.09	0.25	0.43	0.82	0.58	0.07	0.33	0.38	0.70	1.00	0.55	0.96	0.34	0.40	0.20	0.64	0.89	0.57
Nuh	0.97	0.46	0.00	0.00	0.64	0.41	0.89	0.63	0.14	0.14	1.00	0.83	0.21	0.55	0.01	0.36	0.04	0.17	1.00	0.00	0.26
Palwal	0.68	0.04	0.36	0.04	0.34	0.29	0.98	0.26	0.00	0.11	0.75	0.74	0.19	0.43	0.88	0.29	0.20	0.20	0.44	0.70	0.45
Panchkula	0.95	0.46	0.95	0.26	1.00	0.73	0.96	1.00	1.00	0.00	0.00	0.92	0.32	0.60	0.89	0.10	0.00	0.05	0.10	0.85	0.33
Panipat	0.23	0.06	0.73	0.35	0.38	0.35	0.80	0.26	0.04	0.21	0.92	0.35	0.39	0.42	0.68	0.26	0.42	0.35	0.10	0.81	0.44
Rewari	1.00	0.57	0.72	0.19	0.27	0.55	0.93	0.68	0.06	0.15	0.06	0.60	0.62	0.44	0.91	0.42	0.41	0.25	0.48	0.81	0.55
Rohtak	0.93	0.00	0.74	0.15	0.37	0.44	0.95	0.68	0.05	0.19	0.78	0.98	0.00	0.52	0.91	0.40	0.03	0.19	0.07	0.78	0.40
Sirsa	0.30	0.57	0.61	0.12	0.09	0.34	0.70	0.84	0.06	1.00	0.60	0.48	0.44	0.59	0.80	0.89	0.81	0.36	0.83	0.78	0.74
Sonipat	0.45	0.63	0.73	0.19	0.53	0.51	0.63	0.51	0.18	0.39	0.20	0.68	0.19	0.40	0.33	0.65	0.46	0.33	0.62	0.81	0.53
Yamunanagar	0.43	0.55	0.70	0.13	0.83	0.53	0.75	0.77	0.56	0.24	0.71	0.48	0.21	0.53	0.83	0.23	0.46	0.51	0.99	0.74	0.62

(Note: EE1 = Quantity of pesticides consumed in agriculture, EE2 = Milk produced per unit of livestock, EE3 = No. of households served by each bank in the region, EE4 = Per-capita income at current price, EE5 = The total amount of rainfall received in a year, EEI=Economical Sustainability Index; ES1 = Cropping intensity: Ratio of cropped area to net sown area, ES2 = Livestock density: Number of livestock per unit of land, ES 3 = Total land area covered by forests in the region, ES4 = Total area of land under cultivation for crops, ES5 = Variation in annual rainfall from the average rainfall pattern over a period, ES6 = Groundwater development stress, ES7 = Level of pressure on groundwater resources due to their extraction and usage, ESI=Ecological Sustainability Index; SE1 = Infant death/mortality: Rate of infant deaths per 1,000 live births, SE 2 = Total length of roads in kilometers, SE 3 = Number of electricity connections for agriculture, SE 4 = Number of Primary Agricultural Cre dit Societies for farmers, SE 5 = No. of officially Govt. recognized schools, SE6 = Teacher Pupil Ratio: Students per teacher in primary schools, SEI=Social Sustainability Index)

TABLE 3. RANKINGS OF DISTRICTS IN HARYANA ACROSS LIVELIHOOD SUSTAINABILITY DIMENSIONS

District	Economic Sustainability		Ecological Sustainability		Social Sustainability		Livelihood Sustainability	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Ambala	0.52	VIII	0.45	XVI	0.65	IV	0.55	VII
Bhiwani	0.44	XIII	0.58	IV	0.56	XI	0.54	IX
Charkhi Dadri	0.48	XI	0.49	XIV	0.41	XVII	0.47	XVI
Faridabad	0.58	IV	0.27	XXII	0.25	XXII	0.38	XXI
Fatehabad	0.53	VII	0.53	VII	0.59	VIII	0.55	VIII
Gurgaon	0.81	I	0.51	XI	0.36	XIX	0.58	II
Hisar	0.37	XVIII	0.58	III	0.58	IX	0.49	XIV
Jhajjar	0.58	III	0.51	XIII	0.47	XIV	0.53	X
Jind	0.45	XII	0.51	XII	0.59	VII	0.52	XI
Kaithal	0.37	XIX	0.38	XXI	0.63	V	0.46	XVII
Karnal	0.40	XVII	0.53	IX	0.77	I	0.59	I
Kurukshetra	0.50	X	0.45	XV	0.68	III	0.56	V
Mahendragarh	0.43	XV	0.55	V	0.57	X	0.52	XII
Nuh	0.41	XVI	0.55	VI	0.26	XXI	0.41	XIX
Palwal	0.29	XXII	0.43	XVIII	0.45	XV	0.38	XXII
Panchkula	0.73	II	0.60	I	0.33	XX	0.57	III
Panipat	0.35	XX	0.42	XIX	0.44	XVI	0.40	XX
Rewari	0.55	V	0.44	XVII	0.55	XII	0.52	XIII
Rohtak	0.44	XIV	0.52	X	0.40	XVIII	0.45	XVIII
Sirsa	0.34	XXI	0.59	II	0.74	II	0.56	IV
Sonipat	0.51	IX	0.40	XX	0.53	XIII	0.48	XV
Yamunanagar	0.53	VI	0.53	VIII	0.62	VI	0.56	VI

urban planning, and green spaces, such as the Sukhna Lake. These factors contribute significantly to its top ranking. However, Faridabad ranks lowest in Ecological Sustainability (Rank XXII) with an ESI value of 0.27, driven by rapid urbanisation, industrial growth and the over-exploitation of natural resources, including water and land, leading to severe ecological degradation. The district's lack of effective environmental management practices underscores its challenges in achieving sustainability. When considering Social Sustainability, Karnal stands out with a SEI value of 0.77 (Rank I), benefiting from effective social policies, comprehensive healthcare systems and strong educational facilities. This focus on equity, poverty reduction and social well-being contributes to its top rank in this dimension. In contrast, Nuh ranks lowest in Social Sustainability (Rank XXII) with a SEI value of 0.26, which can be attributed to high levels of poverty, inadequate access to quality healthcare, limited educational opportunities and a lack of social services. These factors have led to poor social equity and hindered the district's overall development. This analysis of district rankings provides critical insights into regional sustainability performance across the state of Haryana. Districts such as Gurgaon (Rank I in Economic Sustainability and Rank II in Livelihood Sustainability), Karnal (Rank I in

TABLE 4. DISTRIBUTION OF DISTRICTS IN HARYANA ACROSS DIFFERENT LIVELIHOOD SUSTAINABILITY CATEGORIES

Category		Less sustainable ($0.00 \leq x \leq 0.25$)	Medium sustainable ($0.26 \leq x \leq 0.50$)	Sustainable ($0.51 \leq x \leq 0.75$)	Highly sustainable ($0.76 \leq x \leq 1.00$)
Economic Sustainability	District	-	Palwal, Sirsa, Panipat, Kaithal, Hisar, Karnal, Nuh, Mahendragarh, Rohtak, Bhiwani, Jind, Charkhi Dadri and Kurukshetra	Sonipat, Ambala, Fatehabad, Yamunanagar, Rewari, Faridabad, Jhajjar and Panchkula	Gurgaon
	Total	0 (0.00)	13 (59.09)	8 (36.39)	1 (4.52)
Ecological Sustainability	District	-	Faridabad, Kaithal, Sonipat, Panipat, Palwal, Rewari, Ambala, Kurukshetra and Charkhi Dadri	Jhajjar, Jind, Gurgaon, Rohtak, Karnal, Yamunanagar, Fatehabad, Nuh, Mahendragarh, Bhiwani, Hisar, Sirsa and Panchkula	-
	Total	0 (0.00)	9 (40.91)	13 (59.09)	0 (0.00)
Social Sustainability	District	Faridabad	Nuh, Panchkula, Gurgaon, Rohtak, Charkhi Dadri, Panipat, Palwal and Jhajjar	Sonipat, Rewari, Bhiwani, Mahendragarh, Hisar, Fatehabad, Jind, Yamunanagar, Kaithal, Ambala, Kurukshetra and Sirsa	Karnal
	Total	1 (4.52)	8 (36.39)	12 (54.58)	1 (4.52)
Livelihood Sustainability	District	-	Palwal, Faridabad, Panipat, Nuh, Rohtak, Kaithal, Charkhi Dadri, Sonipat and Hisar	Rewari, Mahendragarh, Jind, Jhajjar, Bhiwani, Fatehabad, Ambala, Yamunanagar, Kurukshetra, Sirsa, Panchkula, Gurgaon and Karnal	-
	Total	0 (0.00)	9 (40.91)	13 (59.09)	0 (0.00)

(Note: Figure inside parentheses indicates the percentage of the total number of districts in Haryana)

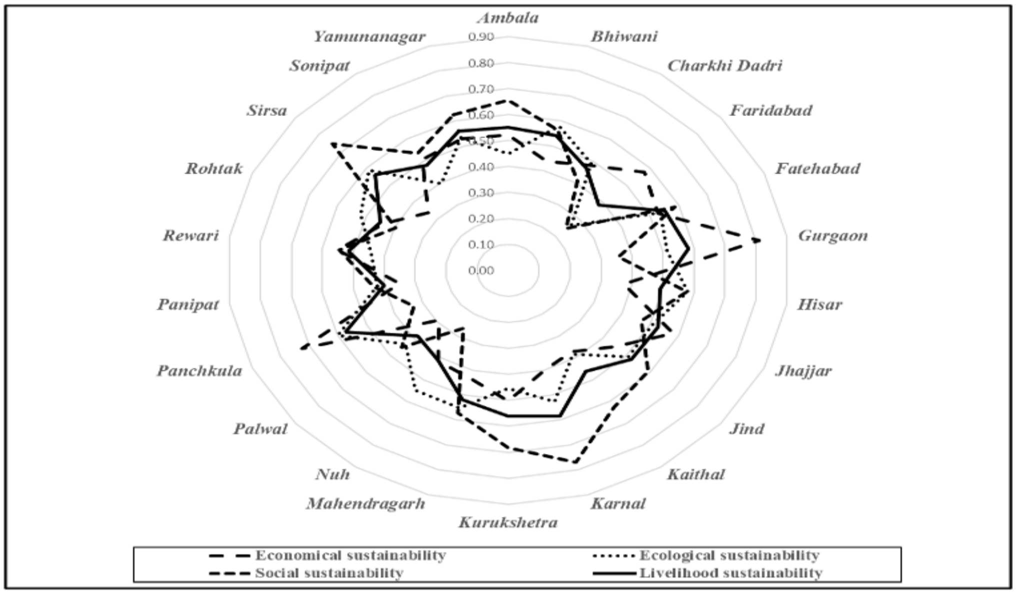

FIGURE 1. DISTRIBUTION OF LIVELIHOOD SUSTAINABILITY DIMENSIONS ACROSS DISTRICTS OF HARYANA

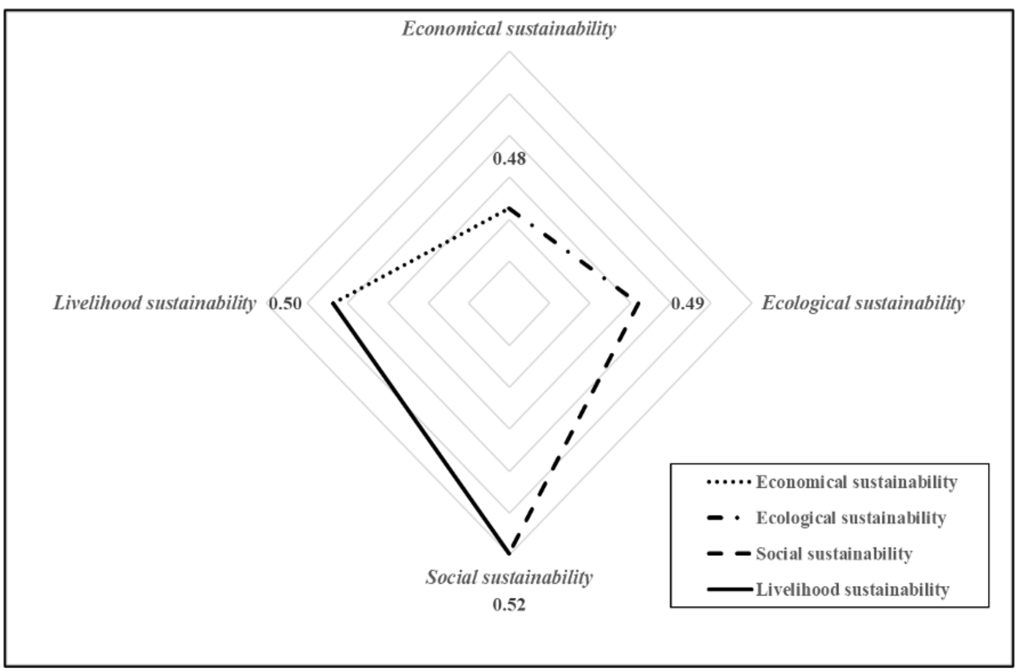

FIGURE 2. AVERAGE DISTRIBUTION OF LIVELIHOOD SUSTAINABILITY DIMENSIONS IN THE STATE OF HARYANA

Social Sustainability and Livelihood Sustainability) and Panchkula (Rank I in Ecological Sustainability) exemplify the benefits of a balanced approach that integrates economic growth, environmental protection and social equity. In contrast, districts like Palwal (Rank XXII in Economic Sustainability, Rank XXII in Ecological Sustainability and Rank XXII in Livelihood Sustainability), Faridabad (Rank XXII in Ecological Sustainability) and Nuh (Rank XXII in Social Sustainability) face significant challenges that need to be addressed through targeted interventions aimed at improving infrastructure, enhancing social services and adopting sustainable environmental practices.

Table 4 reflects significant regional variations of various districts in Haryana on four key dimensions of livelihood sustainability. In terms of economic sustainability, the majority of districts (59.09%) have been classified as “Medium Sustainable”, indicating moderate progress in economic development. Districts like Sonipat, Ambala and Fatehabad show growth but face challenges in scaling industrialisation and addressing infrastructural gaps. Meanwhile, only eight districts (36.39%) have been categorised as “Sustainable” with a positive economic performance but without reaching the levels of growth seen in Gurgaon. When examining Ecological Sustainability, the “Sustainable” category includes 13 districts (59.09%) such as Jhajjar, Jind and Hisar, reflecting moderate efforts to address ecological concerns. For Social Sustainability, Faridabad ranks in the “Less Sustainable” category due to pressing social challenges, including high poverty levels, inadequate healthcare, and insufficient access to education. In contrast, eight districts (36.39%), including Nuh, Jhajjar and Kaithal, have been classified as “Medium Sustainable” in this dimension. The “Sustainable category”, which includes 12 districts (54.58%), shows better performance in terms of social services and equity. However, no district in this category ranks as “Highly Sustainable”, highlighting the need for further investment in social development and equity.

Overall Livelihood Sustainability, the majority of districts (59.09%) have been classified as “Sustainable”, such as Rewari, Mahendragarh and Bhiwani, which maintain livelihood sustainability through agriculture and small-scale industries. While these districts perform well, there is still room for improvement in terms of infrastructure and service delivery. A further nine districts (40.91%) have been categorised as “Medium Sustainable”, indicating a solid foundation for livelihood sustainability, although challenges such as underemployment and limited access to social services remain.

The analysis of the direct and indirect effects on Economic Sustainability indicators (Table 5) revealed that varying levels of impact from the different indicating variables. The highest direct effect is observed in the quantity of pesticides consumed in agriculture (0.51) and total effect (0.55), indicating that pesticide consumption has a significant role in economic sustainability, with a small positive indirect effect (0.04) showing that while pesticide consumption directly affects agricultural productivity, the indirect impact is marginal. Similarly, Per-capita income at current prices showed a direct effect (0.33) with a substantial indirect effect (0.37), resulting in a total effect of 0.70. This suggests that per capita income is a significant contributor to economic sustainability, with its indirect effect playing a crucial role in determining the region's overall economic status. In contrast, milk production per unit of livestock showed a relatively low total effect (0.09), despite a direct effect of 0.37. The indirect effect here is negative (-0.28), indicating that while milk production has a direct positive impact on economic sustainability, the indirect

TABLE 5. ESTIMATE OF DIRECT AND INDIRECT EFFECTS ON ECONOMIC SUSTAINABILITY

Code	Particulars	Direct Effect	Indirect Effect	Total Effect
	Economic Sustainability Indicators			
EE1	Quantity of pesticides consumed in agriculture	0.51	0.04	0.55
EE2	Milk produced per unit of livestock	0.37	-0.28	0.09
EE3	Number of households served by each bank in the region	0.34	0.27	0.61
EE4	Per capita income at current prices	0.33	0.37	0.70
EE5	The total amount of rainfall received in a year	0.38	0.28	0.66
	Ecological Sustainability Indicators			
ES1	Cropping intensity: Ratio of cropped area to net sown area.	0.36	0.21	0.57
ES2	Livestock density: Number of livestock per unit of land	0.42	0.33	0.74
ES3	Total land area covered by forests in the region	0.39	-0.09	0.31
ES4	Total area of land under cultivation for crops	0.45	-0.09	0.37
ES5	Variation in annual rainfall from the average rainfall pattern over a period	0.56	-0.43	0.14
ES6	Groundwater development stress	0.46	-0.18	0.28
ES7	The level of pressure on groundwater resources due to their extraction and usage	0.46	-0.48	-0.02
	Social Sustainability Indicators			
SE1	Infant death /mortality: Rate of infant deaths per 1,000 live births	0.33	-0.14	0.20
SE2	Total length of roads in kilometres	0.28	0.39	0.67
SE3	Number of electricity connections for agriculture	0.31	0.54	0.85
SE4	Number of Primary Agricultural Credit Societies for farmers	0.29	0.51	0.79
SE5	No. of officially Govt. recognised schools	0.36	0.21	0.57
SE6	Teacher Pupil Ratio: Students per teacher in primary schools	0.21	0.02	0.23
	Livelihood Sustainability indices			
EEI	Economic Sustainability Index	0.73	-0.29	0.44
ESI	Ecological Sustainability Index	0.39	0.18	0.57
SEI	Social Sustainability Index	0.77	-0.20	0.57

effects, possibly due to inefficiencies or resource constraints in the agricultural sector, reduce its overall contribution. The number of households served by each bank in the region showed a positive total effect (0.61), direct effect (0.34) and a moderate indirect effect of 0.27. This highlighted the importance of access to financial services in developing economic sustainability, as both direct and indirect impacts contribute substantially to economic growth. Other indicators, such as the total amount of rainfall received in a year, also show a moderate effect, with both direct effect (0.38) and indirect effect (0.28) contributing to a total effect of 0.66. This suggests that climatic factors, such as rainfall, play a crucial role in supporting agricultural production, thereby influencing overall economic sustainability.

In terms of Ecological Sustainability (Table 5), Livestock density (ES2) showed the highest total effect (0.74) with a direct effect of 0.42 and an indirect effect of 0.33. This indicates that livestock density has a significant positive impact on ecological sustainability, with both direct and indirect factors contributing substantially to its overall effect. Cropping intensity (ES1) exhibited a direct effect of 0.36 and an indirect effect of 0.21, resulting in a total effect of 0.57, which suggests a moderate role in ecological sustainability, as they complement each other to support sustainable agricultural practices. On the other hand, Variation in annual rainfall from the average rainfall pattern over a period (ES5) showed the lowest total effect (0.14) despite a high direct effect (0.56).

This large direct effect indicates that rainfall variation plays a vital role in ecological sustainability; however, the indirect effect (-0.43) considerably diminishes its total contribution, suggesting that variability in rainfall patterns can lead to adverse impacts on overall ecological stability. Similarly, the level of pressure on groundwater resources due to their extraction and usage (ES7) showed a negative total effect (-0.02) with a direct effect of 0.46 and a significant negative indirect effect (-0.48), indicating that the over-extraction of groundwater may be unsustainable, leading to negative ecological consequences. Other ecological indicators, such as Total land area covered by forests in the region (ES3) and Groundwater development stress (ES6), contributed positively to ecological sustainability with direct effects of 0.39 and 0.46, respectively. In contrast, their indirect effects vary in magnitude. These results indicated that environmental factors, such as forest cover and groundwater management, play a key role in maintaining ecological balance.

When examining Social Sustainability (Table 5), the number of electricity connections for agriculture (SE3) stands out with a total effect of 0.85, where the direct effect is 0.31. The indirect effect is 0.54, which highlights that electricity access plays a significant role in promoting social sustainability, particularly in rural agricultural communities, where it substantially contributes to improved living conditions and standards of living. Similarly, Number of Primary Agricultural Credit Societies for farmers (SE4) has a total effect of 0.79, with a direct effect of 0.29 and a substantial indirect effect of 0.51, emphasized the importance of financial support for farmers in ensuring social equity and long-term livelihood security In contrast, Teacher Pupil Ratio (SE6) showed a relatively small total effect (0.23) with a direct effect of 0.21 and a minimal indirect effect of 0.02. This suggests that while the teacher-student ratio is important for ensuring quality education, its indirect impact on social sustainability is limited. Other indicators, such as Infant death/mortality rate (SE1) and Total length of roads in kilometres (SE2), have also shown significant

TABLE 6. IMPACT OF SELECTED INDICATORS ON LIVELIHOOD SUSTAINABILITY IN HARYANA: REGRESSION RESULTS

Dependent variable: Livelihood Sustainability				
Method: ENTER - Ordinary Least Squares				
R^2				= 0.89
Adjusted R^2				= 0.81
Standard error of estimate				= 0.07
Source	Sum of Squares	Degree of freedom	Mean Square	F-Value
Regression	0.34	6.00	0.0567	43.62***
Residual	0.02	15.00	0.0013	
Total	0.36	21.00		
Independent variable	Coefficient	Standard error	t-statistic	P value
Constant (α)	0.65	0.00	7.46	0.00***
Milk produced per unit of livestock (X_1)	0.08	0.02	3.76	0.00***
Per capita income at current price (X_2)	-0.16	0.04	-3.90	0.00***
Total land area covered by forests in the region (X_3)	0.31	0.10	3.19	0.01***
Variation in annual rainfall from the average rainfall pattern over a period (X_4)	-0.11	0.04	-2.71	0.01***
Number of Primary Agricultural Credit Societies for farmers (X_5)	0.13	0.09	2.42	0.02**
No. of officially Govt. recognised schools (X_6)	0.12	0.06	2.44	0.02**

Estimated equation

Livelihood sustainability = 0.65+ 0.08 X_1 - 0.16 X_2 + 0.31 X_3 -0.11 X_4 + 0.13 X_5 + 0.12 X_6 + ε_t

*(Note: Significance levels are indicated as ***, **, *, NS for 1%, 5%,10% and not significant respectively)*

positive impacts with total effects of 0.20 and 0.67, respectively. These results underscore the crucial role of healthcare and infrastructure in promoting social sustainability, particularly in rural areas. The overall Livelihood Sustainability indices (Table 5), including the Economic Sustainability Index (EEI), Ecological Sustainability Index (ESI) and Social Sustainability Index (SEI), revealed strong relationships between the direct and indirect effects of various indicators. The EEI showed a total effect of 0.44, with a direct effect (0.73) and an indirect effect (-0.29), suggesting that economic indicators are crucial for ensuring long-term livelihood sustainability. However, the negative indirect effect may indicate some inefficiencies in the system. Similarly, the ESI has a total effect of 0.57 with a direct effect (0.39) and an indirect effect (0.18), highlighting the significant contribution of ecological indicators. The SEI also showed a total effect of 0.57, with a direct effect (0.77) and an indirect effect (-0.20), which reflects the importance of social infrastructure and services, such as education and healthcare, in supporting livelihoods. However, the negative indirect effect suggested that some social factors may be less effective in certain contexts.

The regression analysis conducted to examine the impact of selected indicators on livelihood sustainability in Haryana (Table 6) provides significant insights into the factors contributing to sustainable livelihoods in the region. The model used Ordinary Least Squares (OLS) regression with the dependent variable (livelihood sustainability) and selected six independent variables. The results suggested that the model explains a substantial portion of the variation in livelihood sustainability. The R^2 value (0.89) indicates that 89 per cent of the variability in livelihood sustainability has been accounted for by the independent variables, implying a strong fit of the model. Additionally, the adjusted R^2 value (0.81) supports this robustness as it accounts for the number of predictors in the model. This suggests that the selected independent variables contribute significantly to explaining the variation in livelihood sustainability. Moreover, the standard error of estimate (0.07) indicated that the predicted values of livelihood sustainability are closely aligned with the actual values, further validating the precision of the model. The F-value (43.62) with a p-value (less than 0.001) confirmed that the regression model as a whole is statistically significant, indicating that the independent variables collectively explain the variation in livelihood sustainability. The p-values for the individual independent variables, all of which are below the 0.05 threshold, confirmed the significance of each predictor in explaining livelihood sustainability.

When examining the coefficients of the independent variables, the results provided important insights into the specific factors driving livelihood sustainability. The constant ($\alpha = 0.65$) suggested that in the absence of the independent variables, the baseline level of livelihood sustainability is moderate. The positive coefficient for milk produced per unit of livestock ($X_1 = 0.08$, $p < 0.001$) indicates that as milk production increases, the sustainability of livelihood improves. This finding highlighted the crucial role of livestock farming, particularly dairy production, in enhancing rural economic stability and contributing to overall sustainability in Haryana (Hatai and Sen, 2008).

The coefficient for per-capita income at current price ($X_2 = -0.16$, $p < 0.001$) is negative, suggesting that higher per-capita income may have an adverse effect on livelihood sustainability. While this might seem unanticipated, it could reflect an imbalance where increasing income is associated with rising consumption or the depletion of natural resources, which may undermine long-term sustainability. Further research is required to explore the relationship between income and sustainability in rural contexts. The total land area covered by forests in the region (X_3 = 0.31, p = 0.01) showed a significant positive relationship with livelihood sustainability. This suggests that forest conservation plays a vital role in promoting sustainability by providing essential ecosystem services, such as soil fertility, water retention, and biodiversity (Koutika et al., 2022). The negative relationship between variation in annual rainfall (X_4 = -0.11, p = 0.01) and livelihood sustainability indicated that greater fluctuations in rainfall patterns posed a significant risk to rural livelihoods. This result underscores the vulnerability of Haryana's agricultural communities to climate change, particularly in terms of unpredictable rainfall that can lead to crop failure and water scarcity. The positive coefficient for the number of Primary Agricultural Credit Societies for farmers (X_5 = 0.13, p = 0.02) suggests that access to agricultural credit is a key factor in supporting the sustainability of farmers' livelihoods. These credit societies provided farmers with access to essential financial resources, enabling them to invest in better farming practices and cope with economic uncertainties (Wang et al., 2018). This finding emphasised the importance of financial inclusion and access to credit facilities for enhancing farmers' resilience and long-term sustainability. Lastly, the coefficient for the number of officially government-recognised schools (X_6 = 0.12, p = 0.02) revealed that increased access to education is positively associated with livelihood sustainability. Education equips individuals with the skills and knowledge necessary for diversifying their livelihoods, improving productivity, and making informed decisions (Huang et al., 2024). This highlighted the critical role of educational infrastructure in rural development and its contribution to sustainable livelihoods. Thus, the overall regression model results highlight several key factors that influence livelihood sustainability in Haryana. Positive contributors include milk production, forest cover, access to agricultural credit, and educational infrastructure, all of which enhance the sustainability of rural livelihoods. On the other hand, higher per-capita income and greater variation in rainfall patterns negatively impacted livelihood sustainability. These findings suggested that policies aimed at environmental conservation, expanding access to credit and education and addressing climate change impacts will be critical for improving livelihood sustainability in Haryana.

IV

CONCLUSION

This study investigated a detailed analysis of livelihood sustainability in Haryana, revealing notable regional disparities in the economic, ecological and social dimensions of sustainability. The findings indicate that districts such as Gurgaon excel in economic sustainability due to their thriving industrial base and well-developed infrastructure, making it one of the most sustainable regions in the state. Similarly, Karnal demonstrated strong performance in social sustainability, particularly in providing electricity connections for agriculture and high access to agricultural credit societies, which contributed significantly to its livelihood sustainability. On the other hand, districts like Palwal and Nuh faced significant challenges, particularly in the social sustainability indicators such as healthcare and educational services. Furthermore, environmental sustainability was a major concern, with Faridabad ranking the lowest in terms of ecological sustainability due to rapid urbanisation and over-exploitation of natural resources, particularly groundwater (ES6 = 0.60). The regression analysis revealed that factors such as milk production, forest cover, and the number of Primary Agricultural Credit Societies were positively correlated with improved sustainability. In contrast, factors like per-capita income and rainfall variability had a negative impact on the long-term viability of rural livelihoods. The findings reveal a need for a multifaceted approach to sustainability, with a specific emphasis on improving infrastructure, enhancing agricultural practices, and addressing environmental concerns such as water scarcity and soil degradation. By focusing on these critical areas, particularly in underperforming districts, targeted interventions can significantly improve livelihood sustainability across Haryana. These results not only shed light on Haryana's current sustainability status but also offer a roadmap for future policy interventions aimed at creating a more resilient and sustainable future for all districts in the state

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