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An Analysis of Agricultural Sustainability in the Hadauti Region of Rajasthan Using an Indexing Approach

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ABSTRACT: One of the effective and adaptable frameworks for analysing a region's agricultural sustainability that considers the issues of ecological security, economic effectiveness, and social equality is the Sustainable Agricultural Index (SAI). This research paper's main objective is to evaluate the many aspects of the Hadauti region's sustainable agricultural development. The current study is analytical and incorporates fourteen Hadauti region blocks as well as nine sub-indicators of three components for the years 2016 to 2020, calculating the Hadauti region's sustainable agricultural index. The sustainable agricultural index of Keshoraipatan was the highest of all the blocks while Ladpura was at the bottom rank. This method works well for evaluating agriculture's sustainable development and developing a comprehensive understanding of the region's socioeconomic and environmental trends. The index values will aid in prioritising the most susceptible locations, and policies will be formulated by those results to increase the agricultural sustainability of the area.

KEYWORDS: Sustainable Agricultural Index; Economic efficiency; Ecological security; Social equity; Agricultural sustainability.

I. INTRODUCTION

A sustainable development is one that "meets the needs of the present without compromising the capacity of future generations to meet their own needs," according to the Brundtland Commission. (World Commission on Environment and Development 1987). This definition has received significant praise and has been used to demonstrate that intergenerational equity is a key component of sustainable development. In India, agriculture is dealing with several difficulties that when combined lead to sustainability problems. The signs of agricultural instability include subpar growth, a lack of desired income, and farmers getting distracted or leaving the industry. The causes are the natural resource depletion and the socioeconomic conditions of the farmers. The efficient production of safe, high-quality agricultural goods while preserving the social and economic circumstances of farmers, their workers, and the surrounding communities is known as sustainable agriculture.

Developing technology and practices that do not negatively impact environmental goods and services, are practical for farmers to use, increase food productivity, and do not negatively impact the environment are the main topics of concern for those interested in agricultural sustainability. Furthermore, it is recognized that sustainability in agricultural systems tackles a number of more general economic, social, and environmental issues as well as concepts of resilience and persistence. Overcrowding, excessive irrigation, biodiversity loss, dwindling agricultural genetic diversity, and climate change are a few of the issues that could jeopardise the continued viability of agricultural systems in the future, especially at the local and regional levels. After the green revolution, agricultural production expanded significantly, but because of the repeated use of high-yielding crops, chemical fertilizers, pesticides, and water, the environment and the quality of the land were negatively impacted. Therefore, the country faces a significant problem in terms of agricultural sustainability.

II. OBJECTIVES OF THE STUDY

The major objective of the present research is to estimate and construct the Sustainable Agricultural Index and its pattern in the study area of the Hadauti region in Rajasthan.



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III. METHODOLOGY

In order to evaluate spatiotemporal variation in the relative level of agricultural sustainability in the Hadauti region, we applied the comparative methodology that UNDP used to develop the HDI on an international basis. 1990's United Nations Development Programme.

Three sustainable development of agriculture (SDA) propositions characterise the analytical approach necessary for operationalizing Sustainable Livelihood Security in the form of an Index. (Saleth and Swaminathan 1993). Ecological security, economic efficiency, and social equality in both intra- and interregional contexts are the first three dimensions of the SDA. Second, rather than being absolute in both time and location, sustainability evaluation needs to be relative to account for the dynamic and contextual character of SDA. Third, the multidimensional conception of SDA necessitates that the Index be a composite of three interacting component indexes, namely the ecological security index (ESI), the economic efficiency index (EEI), and the social equity index (SEI), for it to account for both the conflicts and synergies among the ecological, economic, and equity aspects of SDA. (Hatai and Sen 2008). Numerous studies have demonstrated the selection and validation of these components' indicators for the assessment of a given entity's sustainable development. (MS Swaminathan Research Foundation 1993; Saleth 1993; Saleth and Swaminathan, 1993; Singh and Hiremath 2010).

Let Xijk and Slijk represent the value of the ith variable, a jth component of the kth state and the index for the ith variable, a jth component of the sustainability index (SI) of the kth state respectively. Accordingly, the SI of the respective component will be

$$SI_{ijk=\frac{X_{ijk-Min_{ijk}}}{Max_{ijk-Min_{ijk}}}}$$
for variables with positive implications
$$SI_{ijk=\frac{Max_{ijk-X_{ijk}}}{Max_{ijk-Min_{ijk}}}}$$
for variables with negative implications

where i = variables 1, 2, 3, ..., I; j = components 1, 2, 3, ..., J; k = states 1, 2, 3, ..., K. After working out the SI for all variables, the indices for different components (economic, social, and ecological) were estimated as a simple mean of the indices for the respective variables as

$$SI_{ijk} = \frac{\sum_{i=1}^{I} SI_{ijk}}{I}$$

where j = 1, 2, 3, ..., j; k = 1, 2, 3, ..., K.

If the index value is 1, it does not mean that there are no opportunities for further development or that agriculture is completely sustainable; rather, it means that other blocks can develop further by modelling themselves after the ideal block or region. Like the 0.00 index number, it doesn't necessarily mean that there is no agricultural sustainability, but it does mean that these regions need to receive more attention and that appropriate policy actions need to be taken for their overall agricultural development. (Deshmukh and Patil-2018)

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IV. STUDY AREA

Key Map



The study area is located in the southeastern part of Hadauti Plateau in Rajasthan, between $24^{\circ}25^{1}$ to $25^{\circ}51^{1}$ North latitudes and $75^{\circ}15^{1}$ to $76^{\circ}45^{1}$ East longitudes. The total geographical area of this region is 14481.6 square kilometres. The east to west length of the region is 155 km and the north to south length is 180 km. This region includes the entire Bundi district, the entire Kota district except Ramganj Mandi tehsil, the entire Baran district except Chhabra, Kishanganj and Shahbad tehsils and Khanpur tehsil of Jhalawar district (Yadav, Khan and Sharma). There are 15 tehsils in this region, in which there are 2278 inhabited villages and 19 towns, the main ever-flowing river of this region is Chambal, whose tributaries are Kali Sindh, Parvan, Parvati and Mej. The climate here is semi-arid and sub-arid. Agriculture is the main occupation of the population here. Hadauti Region is an important industrial and agrarian region in the State of Rajasthan. There are 14 blocks in the region and the unit of study is block, as the data has been used for blocks and used for analysis.

Indicators selected for the study, its scope in sustainable agricultural development.

Since not all of the Sustainable Development Index (SDI) components can be measured directly, appropriate indicators are needed to evaluate them. Since the same indicators can be used to analyse many components, it is crucial to assess the requirements for choosing the best location-specific indicators and look at how they relate to one another. (Table 1).

Ecological Security Indicators	Economic Efficiency Indicators	Social Equity Indicators
Forest Area (Hectare)	The area under Food crops (Hectare)	Sex Ratio
Population Density (Sq. Km)	Fertilizer Consumption (MT)	Total Literacy
Total Livestock	Net Irrigated Area (Hectare)	Household BPL

Table 1: Selected sets of variables for agricultural sustainability index



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The sets of factors listed in Table 1 were ultimately selected for creating the agricultural sustainability indices based on a review of the literature and the availability of block-level data. The indicator-wise details are as follows.

Forest Area

Forests are the fundamental biological systems that control the health of economic systems like agriculture by providing essential ecosystem services. As a result, it was decided that the percentage of the land covered by forests would have a positive impact on the sustainability of agriculture. The presence of forests is a crucial indicator for preserving natural harmony, reducing pollution, and absorbing greenhouse gases.

Population density

Any geographical area's human population will be a good indicator of the demand for and pressure on its ecological systems. As a result, population density was considered one of the ecological variables and a variable that negatively influenced the sustainability of agriculture in the Indian setting. Intense pressure on the natural resource base, maximum levels of pollution, and environmental degradation are all caused by higher human density.

Total livestock

Agriculture's crop systems are complemented and augmented by the livestock. On the one hand, they provide food and nutrition to the farm families and other populations, as well as inputs to agriculture like manure and draught power. On the other hand, cattle rely on the crop sector for their fodder and feed, and as a result, they work together to support agriculture in various ways. Therefore, in the ecological dimensions, the quantity of animals was also considered a variable. The biggest water use and methane emissions come from livestock. The vast nature of animal rearing, which is the predominant pattern in Indian conditions, will eventually have a negative effect because it raises the burden on natural resources.

The area under food crops

The economic independence of a particular family or region in terms of locally accessible food will be explained by food-grain productivity. Thus, this plays a necessary part in determining the sustainability indices. The power of the economic components will increase as sustainable productivity rises. The area covered by the main food grains in a state is measured in hectares. This has a positive impact on the income of farmers.

Fertilizer consumption

The usage of fertiliser, which is now the foundation of farming, is another crucial factor. Regarding the sustainability of agriculture, it has two sides: a positive side and a negative side. The benefit is that it aids in enhancing the nutritional needs of crops, resulting in increased output and productivity. On the other hand, the negative side has a long-term damping effect on the health of the soil, resulting in salinity and alkalinity, which is bad for agriculture's sustainability. We have taken into consideration the favourable aspect as it pertains to economic efficiency.

Net irrigated Area

Net irrigated area is crucial to increasing agricultural productivity and soil fertility while maintaining agricultural economic efficiency. It encourages the planting of several commercial crop varieties that can increase farmers' incomes and enhance rural life. This has a positive effect.

Sex ratio

One aspect of social equity is the sex ratio. Gender disparity is a concern in most developing nations. Including more women in the workforce will aid in a country's growth since they must be acknowledged as a working population. In addition, the empowerment of women through increased employment opportunities or labour participation is a social development indicator that contributes to the sustainability of the nation's agriculture and, consequently, to overall economic growth. This has a positive effect.

Literacy rate

The literacy rate is a key factor in the process of women's empowerment and the development of the nation since it explains the educational status of a household. It shows how women can participate in society and the economy while also contributing to population stabilization. This has a positive effect.



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Household BPL

We used the variable number of households that fall below the poverty level for the social equity measure. It is a crucial indicator of the underprivileged sector of society and the low standard of living. The degree of social and economic inequality in the blocks will increase as the percentage of BPL households increases. Therefore, we have interpreted it as a negative predictor of agricultural sustainability.

	Ecological Security Indicators			Econ	omic Effic Indicators	Social Equity Indicators			
Blocks	Forest Area (Hectare)	Population Density (Sq. Km)	Total Livestock	under Foodcrops (Hectare)	Fertilizer Consumption (MT)	Net Irrigated Area (Hectare)	Sex Ratio	Literacy Rate total	Household BPL
Bundi	27531	260	105324	62962	17811	58758	927	63.6	5733
Hindoli	44564	165	218500	65826	59814	39844	925	53.92	10624
Nainwan	20990	165	159680	70268	73110	31706	916	57.83	6191
K.Patan	14572	203	166438	72935	22890	116666	933	68.31	7301
Talera	34044	171	101875	41567	19150	44454	922	56.15	3835
Khanpur	25339	184	140375	39652	9749	56804	932	70.04	10985
Itawa	6592	200	101654	49364	15787	60080	931	67.3	7853
Sultanpur	8002	185	116489	59816	16026	61796	929	71.51	7344
Ladpura	78613	730	211374	44947	10240	37341	900	81.71	8390
Sangod	3130	177	132793	31019	17178	36486	935	70.72	6338
Baran	469	339	79599	34470	9992	48889	928	75.27	3878
Anta	3050	231	152061	61176	13335	70888	928	68.49	7065
Atru	14895	177	93595	36999	11196	50715	925	69.79	6467
Chipabarod	32010	205	126292	34880	9197	37035	937	60.67	10811

Table 2: Data for various Indicators in Hadauti 2016-2020

Source: District Statistical outline of Baran, Bundi, Jhalawar and Kota-2017-2021

We estimated index values for ecological security, economic efficiency, and social justice indicators using the sustainable index (SI) of representative values. By taking the arithmetic mean of each of its component indices and using the formula that results in the composite index, the value of the sustainable agriculture index for the entire region is determined. The ecological environment has undergone major changes because of human activity, changes that may have an immediate impact on a region's ecological security. The rapid urbanisation process and the effects it has on the local environment and ecosystem services have significant effects. Agricultural practices have an impact on ecology because they change the environment (Chambers 1986). The secondary data of nine indicators has been collected from various sources such as the statistical outline of Baran, Bundi, Jhalawar and Kota Districts (2016-2020), District Census Handbook of Baran, Bundi, Jhalawar and Kota Districts (2011). The data given in Table 02 is an average of time series data of five years i.e., 2016 to 2020. The situation is examined over five years, and in accordance, policy recommendations are made for ecological security, economic effectiveness, and social equality, all of which will contribute to the sustainable agricultural growth of Rajasthan's Hadauti region. The indicator-wise indices were worked out for the data given in Table 2. Table 3 shows the indices values for the assessment of SAI in the Hadauti region.



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Table 3: Indices for various Indicators in Hadauti 2016-2020

	Ecological Security			Econ	omic Effic	Social Equity			
		Indicators			Indicators	Indicators			
Blocks	Forest Area (Hectare)	Population Density (Sq. Km)	Total Livestock	The area under Food crops (Hectare)	Fertilizer Consumption (MT)	Net Irrigated Area (Hectare)	Sex Ratio	Literacy Rate total	Household BPL
Bundi	0.346	0.832	0.815	0.762	0.135	0.318	0.73	0.348	0.735
Hindoli	0.564	1	0	0.83	0.792	0.096	0.676	0	0.05
Nainwan	0.263	1	0.423	0.936	1	0	0.432	0.141	0.67
K.Patan	0.18	0.933	0.375	1	0.214	1	0.892	0.518	0.515
Talera	0.43	0.989	0.84	0.252	0.156	0.15	0.595	0.08	1
Khanpur	0.318	0.966	0.562	0.206	0.009	0.295	0.865	0.58	0
Itawa	0.078	0.938	0.841	0.438	0.103	0.334	0.838	0.481	0.438
Sultanpur	0.096	0.965	0.734	0.687	0.107	0.354	0.784	0.633	0.509
Ladpura	1	0	0.051	0.332	0.016	0.066	0	1	0.363
Sangod	0.034	0.979	0.617	0	0.125	0.056	0.946	0.605	0.65
Baran	0	0.692	1	0.082	0.012	0.202	0.757	0.768	0.994
Anta	0.033	0.883	0.478	0.719	0.065	0.461	0.757	0.524	0.548
Atru	0.185	0.979	0.899	0.143	0.031	0.224	0.676	0.571	0.632
Chipabarod	0.404	0.929	0.664	0.092	0	0.063	1	0.243	0.024

Source: Authors calculations

Table 4: Construction of Block wise Sustainable Agricultural Index in Hadauti 2016-2020

Block	Ecological Security Index (ESI)	ESI Rank	Economic Efficiency Index (EEI)	EEI Rank	Social Equity Index (SEI)	SEI Rank	Sustainable Agricultural Index (SAI)	SAI Rank
Bundi	0.664	4	0.405	5	0.604	7	0.558	2
Hindoli	0.521	11	0.573	3	0.242	14	0.445	11
Nainwan	0.562	9	0.645	2	0.414	13	0.54	4
K.Patan	0.496	12	0.738	1	0.642	3	0.625	1
Talera	0.753	1	0.186	8	0.558	9	0.499	6
Khanpur	0.615	6	0.17	9	0.482	10	0.422	12
Itawa	0.619	5	0.292	7	0.586	8	0.499	6
Sultanpur	0.598	7	0.383	6	0.642	3	0.541	3
Ladpura	0.35	14	0.138	10	0.454	11	0.314	14
Sangod	0.543	10	0.06	13	0.734	2	0.446	10
Baran	0.564	8	0.099	12	0.84	1	0.501	5



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Anta	0.465	13	0.415	4	0.61	6	0.497	8
Atru	0.688	2	0.133	11	0.626	5	0.482	9
Chipabarod	0.666	3	0.052	14	0.422	12	0.38	13

Source: Authors calculations

Table 04 shows the Ecological security, Economic efficiency, social equity, and Sustainable agricultural index of the Hadauti region from 2016 to 2020 and their respective ranking for the period of 2016 to 2020.

Ecological Security Index (ESI): The index values of ESI give us information about the ecological security of the Hadauti region. The study reveals that Talera (0.753) has the highest ecological security followed by Atru (0.688) whereas Anta (0.465) and Ladpura (0.35) had the lowest ecological security. Therefore, Anta and Ladpura must pay quick attention to environmental issues. These issues might include expanding the forest area by planting trees, reducing pollution, preventing overpopulation, adopting ecologically friendly agriculture techniques, etc. Consequently, policies need to be designed to promote ecologically sustainable agriculture practices.

Economic Efficiency Index (EEI): The Hadauti region's economic viability will be analysed with the use of the economic efficiency index. According to the study, Sangod (0.06) and Chipabarod (0.052) had the lowest economic efficiency of all the blocks, while Keshorai Patan (0.738) and Nainwan (0.645) had the highest levels of efficiency. Increasing irrigation area will increase agricultural output, proper fertiliser usage, and area allocated to food crops, among other advantages, as well as helping to increase economic efficiency in agriculture. The income of farmers must be raised to improve their standard of living. The Hadauti region's economic efficiency must therefore get special consideration.

Social Equity Index (ESI): Agriculture sustainability is a three-pronged strategy that also considers societal equality. According to the study, Baran (0.84) and Sangod (0.734) had the highest social equity indices during the study period, while Nainwan (0.414) and Hindoli (0.242) had the lowest scores. Social equality needs to get more focus in the process of human development if we are to close the income disparity. According to current data on inequality, the rich are becoming richer, and the poor are getting poorer. Spreading high-quality education, improved health care and suitable rural infrastructure are necessary for the socioeconomic growth of the area.



Sustainable Agricultural Index (SAI): The Sustainable Agricultural Index (SAI) is a composite index of the Ecological Security Index (SEI), Economic Efficiency Index (EEI) and Social Equity Index (SEI) is illustrated in Table



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4. According to the survey, Keshorai Patan (0.625) has the highest agricultural sustainability, followed by Bundi (0.588). However, during the years 2016 to 2020, Chipabarod (0.38) and Ladpura (0.314) account for the lowest agricultural sustainability. Ecological security, economic efficiency, and social equality must all be improved at the same time if agricultural sustainability in Rajasthan's Hadauti region is to be sustained over the long term.

Utilizing the sustainable agriculture index for the years 2016 to 2020, the block-wise agricultural sustainability is estimated. None of the Hadauti block was found to fall into either the very high agricultural sustainability category or the very poor agricultural sustainability category, according to the study. One block, Keshorai Patan, falls under the high agricultural sustainability category, whereas Chipabarod and Ladpura fall under the low agricultural sustainability category. The remaining blocks, however, are all classified as medium agricultural sustainability in table 05.

Table 05:	Categories of Sustainable Agricultural Index ((SAT))
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Very Low	Low	Medium	High	Very High
(Below 0.20)	(0.20 - 0.40)	(0.40 - 0.60)	(0.60 - 0.80)	(More than 0.80)
No Block	Ladpura	Bundi	Keshorai Patan	No Block
	Chipabarod	Hindoli		
		Nainwan		
		K.Patan		
		Talera		
		Khanpur		
		Itawa		
		Sultanpur		
		Sangod		
		Baran		
		Anta		
		Atru		

Source: Authors calculations





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V. CONCLUSIONS

In planning and development units of the Hadauti region, the SAI, a composite index of its three components (ESI, EEI, and SEI), served as a potent policy instrument for identifying the prerequisites for the sustainable development of agriculture. Agricultural sustainability and its three components (ESI, EEI, and SEI) within blocks varied greatly during the reference period, according to a spatiotemporal study based on SAI. The blocks with lower index values across all components and the sustainable agricultural index should receive priority from policymakers. The index values will assist in prioritising the susceptible areas, and policies will be designed in accordance therewith to increase agricultural sustainability. The following are the key suggestions:

- National Forest Policy of 1952 states that the critical minimum forest cover for the plains, plateau, hills, and mountains regions should be 20%, 33.3%, and 66.6% respectively. However, our empirical analysis revealed that only a small number of blocks meet these standards. Ladpura block has over 50% of its area under forest, while five blocks have more than 25% of its area under forest. The government should take steps in five blocks which have less than 10% of its area under forests. Baran block needs special attention as it has less than 1% of its area under forest.
- While literacy is a key barrier in poor nations, contemporary agriculture requires special sets of abilities for practice, which eventually influences the techniques and means of practising agriculture, which in turn affects the agricultural yield and soil health.
- The use of pesticides, fertilizers, and agricultural output must all be balanced out as much as possible under the policies governing the use of fertilisers because overuse of fertilizers hurts agricultural sustainability.
- Since agricultural sustainability is a three-dimensional concept, all its elements—including environment, economy, and equity—must develop concurrently until we reach the highest level of agricultural sustainability. To achieve this, policies must be designed to address all three dimensions. Agro-environmental sustainability and sustainable agricultural practices (SAPs) are essential concepts that need to be brought to the attention of farmers.

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