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Development of Agricultural Sustainability Index for different Regions of Uttar Pradesh, India

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ABSTRACT

Using an indicator approach, the present study develops a composite agricultural sustainability index for different regions of Uttar Pradesh, India. A total of 30 indicators, involving environmental sustainability, social security, and economic security are used. The findings show that the western region ranks best in agricultural sustainability, while the Bundelkhand region ranks worst. Lower agricultural land use intensity, less livestock, lower farmers' perception of natural calamities, less per capita income, less irrigation intensity, less institutional credit, less crop diversification, less awareness of the minimum support price, and less ownership of tractors are the main influencing indicators for lower agricultural sustainability in the Bundelkhand region compared with the western region.

Keywords Agricultural sustainability index, Indicator approach, regions, Uttar Pradesh, Sustainable development goals.

INTRODUCTION

Sustainable agriculture plays an important role in achieving sustainable development goals with regard to food security and environmental conservation (Singh 2020a). Sustainable agriculture relies on sustainable farming practices that reduce greenhouse gas emission, the judicious use of natural resources (i.e., water and soil), and the reduction in negative impacts on the environment and human health (Singh 2020b). Sustainable farming practices can be driven by various factors, such as the socio-environmental setting, socio-cognitive factors, agricultural institutions, and policy. It is believed that the simultaneous achievement of sustainability, profitability, and productivity in the agricultural sector requires the development and utilization of appropriate technologies derived from agricultural research and the extension of technological innovations (Suresh *et al.* 2022). Further, agriculture remains to be a great

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player in the generation of revenue and a source of food for many people all over the world (Jatav and Kalu 2023). Sustaining and improving both economic capability and life quality are central to the Sustainable Development Goals (SDGs), which aim to meet people's needs over the long-term without causing irreversible harm to the environment and renewable resources, while also reducing the use of non-renewable resources (DeClerck *et al*. 2016). SDG-2 (zero hunger), SDG-12 (responsible consumption and production), SDG-13 (climate action), and SDG-15 (life on land) all regard agriculture as a crucial component of sustainable development by the year 2030 (Jatav 2021). Natural resources should be utilized more efficiently and waste should be cut down on, if we want to increase overall output and productivity per unit of land. In addition, any harmful outcomes such as pollution, must be reduced or entirely eliminated from the system (Jatav 2020, Jatav and Singh 2023, Mishra *et al*. 2023).

As far as the contribution of agriculture to the Indian growth story is concerned, agriculture alone generated 42% of employment and 16% of the Gross Domestic Product (GDP), and land accounts for 60% of the total geographical area (World Bank 2016). Despite being a significant source of employment, the share of agriculture in GDP has been on the decline over the last 60 years, going from around 54% in 1960-61 to 16% in 2020-21 (GoI 2021). The major reasons for the decline include climate change (Jatav 2022, Jatav Kalu 2022), poor infrastructure, poor management of agricultural markets, farmers' poor socio-economic conditions, inefficient state agricultural policy execution, and farmers' lack of understanding of agricultural technology (Swami *et al.* 2018).

Nowaday, India is facing a four-dimensional agricultural crisis of declining farm income, rising farm expenditure, depletion of natural resources, and impaired ago-biodiversity (GoI 2020, Singh 2020a, Jatav and Kalu 2023). Additionally, there is a positive correlation between average farm revenue and farm size. However, the percentage of large farms fell from 6% to 3%, while the small farms rose from 59% to 67% in India from 1991 to 2011 (GoI 2021). According to the report of the Food and Agriculture Organization (FAO 2017), due to rapid urbanization and increased family wealth, the Indian diet is gradually diversifying. The percentage of cereal to overall food spending decreased from 52% in 1972 to 29% in 2006. The dynamics of the food market system and food processing system are impacted by dietary changes in the non-staple food industry in India. The consumption of fertilizer is 165 kg/hm^2 in India, higher than the global average of 138 kg/hm^2, indicating that fertilizer is being used excessively and inefficiently in India, which leads to insect infestation, soil contamination, and crop nutrition issues (World Bank 2016, FAO 2019). Multiple food insecurity is a serious issue, India has a 14.50% prevalence of undernourishment and a 37.90% prevalence of stunting among children under 5 years old, despite concerted efforts to improve nutritional security, which have significantly reduced the population suffering from food insecurity (FAO 2019).

With the above-mentioned evidences, the present study aims to examine the status of agricultural sustainability in different regions of Uttar Pradesh. By using quantitative data and an indicator approach, a new multidimensional agricultural sustainability index for the different regions of Uttar Pradesh was developed. A total of 30 indicators involving environmental sustainability, economic security, and social security are chosen after robust review of literature.

Methodology

Study Area, Data Sources, and Selection of Rational Indicators

Uttar Pradesh (UP) is bounded to the North by Uttarakhand and to the West by Haryana and Delhi, to the South by Rajasthan and Madhya Pradesh and Chhattisgarh, and to the East by Jharkhand and Bihar. With 7.33% of the total land area and 199.8 million residents, Uttar Pradesh is the most populated and fourth-largest state in India. UP has divided into four regions namely Western, Eastern, Central, and Bundelkhand. The climate varies greatly from drought-prone (Bundelkhand region) to flood-prone (Eastern region).

The present study uses district-level secondary

data collected from various sources including Census 2011, NSSO 2019, Ministry of Agriculture and Farmers Welfare, Government of India; Agricultural Census, 2015-16, National Family Health Survey 2019, and Indian Meteorological Department 2020.

After the robust review of the mainstream literature on agricultural sustainability, 30 rational indicators covering three dimensions i.e., environmental sustainability, economic security, and social security of agricultural sustainability were selected to examine the sustainability status of different regions of Uttar Pradesh. A total of 11 indicators namely area under forest, agricultural land use intensity, agricultural chemical use intensity, agricultural pesticide use intensity, groundwater depletion, livestock ownership, rainfall variability, minimum temperature variability, maximum temperature variability, cropping intensity, and farmers' perception on natural calamities were considered for the development of an environmental sustainability index. Further, a total of 11 indicators namely man-land ratio, per capita income, irrigation intensity, road transportation, institutional credit, food grain productivity, crop diversification, awareness of minimum support price, working in the MGNREGA, agricultural training, and tractor ownership were considered for the development of economic security index. Lastly, 8 indicators namely literacy rate, infant mortality rate, sex ratio, knowledge sharing, joint family, working population, remittance, and membership of agricultural credit societies were considered for the development of a social security index.

Estimation Method: Indicator Approach

The present study used an indicator approach to standardize the data as the study used differential data, and it is a prerequisite to standardize the data before calculating the agricultural sustainability index. The advantage of the indicator approach is that scholars can create agricultural sustainability index at any level like household, village, district, State, or country level. The indicator technique has been extensively used in the planning procedure and in the dissemination of policy information because of its many advantageous aspects. The ability to identify, prioritize, and rank the most important factors; clearly and concisely communicate policy objectives and progress; and consolidate a large volume of information into a format that is easy to comprehend and evaluate the current state of performance for complex and elusive fields that cannot be directly measured (Singh and Alka 2019).

Standardization of the value of Indicator

Before calculating agricultural sustainability index, the nature of data and the research objectives of the composite indicator should be taken into consider in the standardize process (Chetri *et al*. 2022). To standardize indicators into a common range (0, 1) based on their functional link with agricultural sustainability, this study utilized the min-max approach (Iyengar and Sudarshan 1982). Equations 1 and 2 were adopted for larger-better-type and smaller-worse-type indicators, respectively.

$$Z_{ij} = \frac{X_{ij} - Min(X_{ij})}{Max\,(X_{ij}) - Min(X_{ij})} \quad (1)$$

$$Z_{ij} = \frac{Max\,(X_{ij}) - X_{ij}}{Max\,(X_{ij}) - Min(X_{ij})} \quad (2)$$

$$i=1,2,....I \text{ and } j=1,2,....$$

Where Z_{ij} is the standardize value of i^{th} indicator in jth region, X_{ij} is actual value of ith indicator in j^{th} region; $max(X_{ij})$ and $min(X_{ij})$ are the maximum and minimum values of ith indicator in the j^{th} region, respectively.

Assigning Weight

Given the assignment of appropriate weight for different components is an important issue in the construction of an index, we adopted the statistical weight method (Iyengar and Sudarshan 1982). Equations 3 and 4 were used to calculate weights.

$$\left[Wi = \frac{k}{\sqrt{(Var(Z_{ij})}} \right] \quad (3)$$

Where,

$$\left[k = \frac{1}{\left\{ \sum_{i}^{I} = 1 \frac{1}{\sqrt{Var(Z_{ij})}} \right\}} \right] \quad (4)$$

Where W_i is the weight of i^{th} indicator, var(Z_{ij}) is variance of standardize value, and k is calculated using equation 4. The calculated weights were used to construct the component index P_j for j^{th} region using Equation (5).

$$P_j = \frac{\sum_{i}^{I=1} Z_{ij} * W_i}{\sum_{i}^{I=1} W_i} \quad (5)$$

Finally, the agriculture sustainability index for each region is calculated, the average of three components i.e., environmental sustainability index, economic security and social security.

RESULTS AND DISCUSSION

Environmental Sustainability Index (ENSI)

Among the regions of UP, the central region (index score i.e., 0.538) was relatively more ecologically sustainable, whereas the Bundelkhand region (index score i.e., 0.412) was significantly less environmentally sustainable as far as environmental sustainability indices are concerned (Table 1). According to the cross-indicator analysis, the main influencing indicators for lower environmental sustainability in the Bundelkhand region were relatively less agricultural land use intensity, less livestock ownership, and lower farmers' perceptions of natural calamities.

Land conversion, most often from environmentally sensitive regions to agricultural land is triggered by the pressure of food production. For example, when natural habitats like tropical forests and temperate grasslands are converted to farmland, vital ecosystem services are lost (Foley *et al.* 2005, Rodrigues *et al*. 2013). Productivity has decreased as a direct consequence of the rise of monoculture and mono-cropping. Therefore, agricultural land use intensity has defined as the ratio of net sown area to total geographical area. The agricultural land use intensity was highest in the central region i.e., 74%, while it was lowest in Bundelkhand region i.e., 65.14%.

The livestock sector is an important part of the global food system, contributing to poverty alleviation, food security, and the growth of agricultural production. In 2019, livestock sector generated 40% of worldwide agricultural outputs and supported the livelihoods and food and nutrition security of about 1.30 billion people (FAO 2019). The recent estimates show that about 84.02% of farmers in the central region owned livestock, while the corresponding figure for the Bundelkhand region was only 72.25%.

Assessing adaptation and attaining agricultural

Table 1. Region wise Environmental Sustainability dimension of Agricultural Sustainability.

Indicators	Western Region	Eastern Region	Central Region	Bundelkhand Region
Area under Forest	0.495	0.165	0.219	0.220
Agricultural Land Use Intensity	0.398	0.255	0.490	0.227
Agricultural fertilizer use Intensity	0.631	0.663	0.619	0.485
Agricultural Pesticide use Intensity	0.652	0.872	0.819	0.734
Groundwater Depletion	0.429	0.326	0.336	0.206
Livestock Ownership	0.522	0.689	0.692	0.091
Rainfall Variability	0.514	0.718	0.627	0.451
Minimum Temperature Variability	0.634	0.313	0.582	0.430
Maximum Temperature Variability	0.318	0.729	0.658	0.594
Cropping Intensity	0.407	0.511	0.240	0.488
Farmers' perception on natural calamities	0.599	0.539	0.636	0.608
Environmental Sustainability Index	0.509	0.525	0.538	0.412
Rank	3	2	1	4

Source: Authors estimation, 2023.

Table 2. Region wise Economic Security dimension of Agricultural Sustainability.

Indicators	Western Region	Eastern Region	Central Region	Bundelkhand Region
Man-land Ratio	0.660	0.244	0.417	0.381
Per Capita Income	0.458	0.464	0.352	0.098
Irrigation Intensity	0.504	0.482	0.658	0.460
Road Transportation	0.428	0.657	0.578	0.320
Institutional Credit	0.471	0.520	0.427	0.413
Food grain Productivity	0.416	0.557	0.402	0.340
Crop diversification	0.231	0.113	0.238	0.222
Aware of minimum support price	0.602	0.358	0.430	0.440
Working in the MGNREGA	0.486	0.411	0.582	0.405
Agriculture Training	0.154	0.133	0.217	0.263
Tractor ownership	0.414	0.394	0.420	0.266
Economic Security Index	0.439	0.394	0.429	0.328
Rank	1	3	2	4

Source: Authors estimation, 2023.

sustainability requires an examination of farmers' perception on climate change. Farmers' opinion on climate change is significantly impacted by the time and types of climate change events they commonly witness (Singh 2020a). Due to the unpredictability of weather extremes, farmers must take immediate action to mitigate losses. Farmers have a tough time making decisions under these conditions because of the little time it takes to receive and analyse information before making a choice (Jatav 2022). About 74.45% of farmers in the central region perceived that natural disaster like drought is responsible for crop loss, while farmers in Bundelkhand region was only 65.14% perceived that natural disasters are damaging their crops. The main reason for less perception of climate change was asymmetric accessibility of information (Singh 2020a).

Economic Security Index (ESI)

The most crucial component of agricultural sustainability in the economic security index. Among the region, the results show that economic security was highest in western region (index score i.e., 0.438), while it was lowest in Bundelkhand region (index score i.e., 0.329). The results of cross-indicator analysis reveal that higher man-land ratio, higher per capita income, higher irrigation intensity, higher accessibility of institutional credit, and higher crop diversification, more awareness of minimum support price, and higher tractor ownership were the main contributing indicators responsible for higher economic security in western region than Bundelkhand region (Table 2).

According to the data, the man-land ratio in the western region was 13 persons/hm^2, whereas it was just 6 persons/hm^2 in the Bundelkhand region in 2011. Further, the per capita income of the western region is ₹45,605.24, while it was only ₹34, 447.66 in 2013. Irrigation helps to augment productivity and farm income with a reduction in risk (Singh and Nayak 2020). Irrigation development is limited by water availability, capital constraint, and technological feasibility nowadays; therefore, high irrigation efficiency is desired. Irrigation intensity in the western region is 148.33%, while it is only 143.63% in the Bundelkhand region in 2019.

Farmers' access to credit is essential since it allows them to make necessary investments and facilitates the introduction of cutting-edge technology (Jatav and Nayak 2022). India's agriculture plays a special part in the country's macroeconomic framework, and it also plays a key role in reducing poverty, both of which highlight the significance of agricultural financing. Since the beginning of India's planned development period, the country's leaders have recognized the vital role that agricultural finance plays in encouraging agricultural growth and development. In order to pay for either short-term crop loans or long-term farm investment loans, farmers rely on a wide variety of credit options. Many farmers still seek financing from non-institutional sources like money lenders, despite the government's best efforts to channel institutional finance for the agricultural sector (Kumar *et al.* 2015). In 2019, it has been shown that although 65.90% of western region farmers have used institutional loans, while corresponding figure was just 55.21 % in Bundelkand region.

The aim of crop diversification is to increase crop portfolios to avoid farmers relying on a single crop to generate income. Crop diversification can be one of the important technologies for increasing farmers' income to a certain extent and also an important stress-relieving option for the economic growth of the farming community (Jatav 2022). It is observed that about 22.23% of farmers in the western region have diversified their cropping patterns in favor of cash crops and generating extra income, while only 1.32% of farmers have diversified their cropping pattern in the Bundelkhand region.

In the present of procurement, a farmer can refuse to settle price below the minimum support price, if he knows the minimum support price (Chand 2003). If he does not know the minimum support price of crops, traders and middlemen will turn to be exploitative and offer price less than the minimum support price (Chand 2008). In this connection, in the western region, about 25.36% of farmers were well aware of the minimum support price, while the corresponding figure was only 10.50% in the Bundelkhand region. In totality, farmers in the western region have relatively more economic security than those in the Bundelkhand region.

Social Security Index (SSI)

In Uttar Pradesh, social security is the most crucial pillar for agricultural sustainability and livelihood security. The results suggest that social security was comparatively high in the western region (index score i.e., 0.568), while the lowest social security was in the Bundelkhand region (index score i.e., 0.437). According to the cross-indicator analysis, the main influencing indicators responsible for higher social security in the eastern region compared to the Bundelkhand region included a higher sex-ratio, higher knowledge sharing with fellow farmers, higher remittance, and higher membership in agricultural credit society (Table 3).

There is evidence that traditional agriculture tends to prefer men over women, due to the physical power required for agricultural operation (Singh 2020b). The sex ratio is influenced by several social and economic factors such as migration and labor participation in agriculture (Jatav and Singh 2023).

Table 3. Region wise Social Security dimension of Agricultural Sustainability

Indicators	Western Region	Eastern Region	Central Region	Bundelkhand Region
Literacy Rate	0.582	0.646	0.609	0.612
Infant mortality rate	0.456	0.452	0.546	0.459
Sex ratio	0.559	0.704	0.290	0.424
Knowledge sharing	0.421	0.323	0.317	0.226
Joint family	0.430	0.465	0.512	0.509
Working population	0.599	0.518	0.673	0.580
Receiving remittances	1.000	0.391	0.340	0.161
Membership of agricultural credit society	0.499	0.578	0.537	0.522
Social security index	0.568	0.51	0.478	0.437
Rank	1	2	3	4

Source: Authors estimation, 2023.

Gender empowerment is a main factor in agricultural growth. Sex ratio, expressed as number of females per 1000 males, can serve as an indicator of gender justice and social sustainability. In western region, sex-ratio was 893, while it was only 885 in Bundelkhand region.

Knowledge sharing is an important practice to help farmers and other stakeholders in gaining more production. It was observed that about 13.04% of farmers in western region sharing their agricultural experiences with the fellow farmers to cope with climate change and enhance farm income, while only 7.80% of farmers in Bundelkhand region sharing.

A significant part of the debate about the impacts of remittance on sustainable development focuses on specific development indicators that measure poverty and inequality. Remittances tend to reduce poverty, albeit modestly, but the impact on inequality is uneven and sometimes negative. In some cases, increased investment in human capital associated with the receipt of remittance improves health and education outcomes. Financial inclusion has also recently been highlighted as a key tool for maximizing the impact of remittance on development. Overall, the ability of remittance to advance sustainable development is necessarily linked to the policy and investment environment (Singh and Nayak 2020, Jatav and Nayak,

Table 4. Region wise Agricultural Sustainability.

Components	Western Region	Eastern Region	Central Region	Bundelkhand Region
Environmental Sustainability Index	0.509	0.525	0.538	0.412
Economic Security	0.439	0.394	0.429	0.328
Social Security	0.568	0.510	0.478	0.437
Agricultural Sustainability	0.505	0.476	0.482	0.392
Rank	1	3	2	4

Source: Authors estimation, 2023.

2022, Jatav and Kalu 2023). The results show that 100% of farmers in the western region were received remittances from their family members who had living in peri-urban areas, while the corresponding figure in the Bundelkhand region is only 19.12%.

The primary aim of agricultural credit society is to promote saving habits among its members. Besides, the agricultural credit society arranges the supply of agricultural inputs such as seeds, fertilizers, insecticides, etc., and helps its members by providing marketing facilities that could enhance the sale of agricultural products at proper prices in the market (Jatav 2022). It was observed that 13.09% of farmers are member of agricultural credit society in western region, while corresponding figure was 6.84% in Bundelkhand region.

Agricultural Sustainability Index (ASI)

By using equation 5, a region-wise agricultural sustainability index was calculated. The results show that the western region performed well and ranked top as far as environmental sustainability, economic security, social security and on the other hand, the performance of the Bundelkhand region is the worst as far as agricultural sustainability indicators are concerned (Table 4).

Least agricultural land use intensity, less livestock ownership, lower farmers' perception of natural calamities, less per capita income, less irrigation intensity, less institutional credit, less crop diversification, less awareness of the minimum support price, and less ownership of tractors were the main influencing indicators for lower agricultural sustainability in the Bundelkhand region compared with the western region.

Table 5. Validation of Agricultural Sustainability Index.

Parameter	ASI	ENSI	ESI	SSI
ASI	1	0.653	0.490*	0.645*
ENSI	0.653*	1	0.007^{NS}	0.220*
ESI	0.490*	0.007^{NS}	1	-0.120^{NS}
SSI	0.643*	0.220**	-0.120^{NS}	1

Source: Authors estimation, 2023. Note: *, ** and *** indicates level of significance at 1%, 5% and 10%. ASI, ENSI, ESI and SSI stands agricultural sustainability, environmental sustainability, economic security and social security.

Validation of Agricultural Sustainability Index with its Components

Table 5 depicts the validation of the agricultural sustainability index with its three components, i.e., environmental sustainability, economic security, and social security. Spearman's coefficient estimation results show that agricultural sustainability is positively and statistically associated with its components. In other words, agricultural sustainability is determined by environmental sustainability, economic security, and social security in Uttar Pradesh.

CONCLUSION

The present study shows that achieving agricultural sustainable development requires planners and decision-makers to have access to reliable information on agriculture and sustainability. The present study findings have dual applicability. Creating a policy for sustainable agriculture in well-established agro-climatic regions is the first step. Second, the identification of underperforming regions. As present study used 30 robust agricultural sustainability indicators covering environmental, social, and economic dimensions surely help planners and politicians make better decisions on sustainability aspects. Lastly, to boost agricultural revenue, which is relatively immune to natural disasters, authorities should devise novel non-farm job opportunities.

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