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Developing Agricultural Sustainability Index for the Indo-Gangetic Plains of India

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Sustainable Development Goals (SDGs) are the key milestones for economic and agricultural development across the globe. Efforts are directed to make them clear, quantifiable and amenable to monitoring. This is more so for SDGs are directly related to agriculture. The impending threat to agricultural sustainability and its broad dimensions are well documented, but its operationalization has been attempted by a few. The empirical analysis of sustainable agriculture faces many practical difficulties. The available studies are limited in terms of covering the dimensions of the sustainability and their quantification. Total factor productivity (TFP) is a widely used indicator for drawing the inferences about the sustainability of agriculture (Chand et al., 2015) though it says nothing about causes of weak or strong sustainability (Byerlee and Murgai, 2001). A comprehensive approach will need identification and quantification of the indicators and computing a composite index. The development of transparent composite index offers an opportunity to identify the facets of agricultural sustainability that are of practical relevance and can be linked to the interventions for its improvement (Gomez and Gabriel, 2010).

The composite indices so far developed covering all dimensions of sustainability mainly measured relative sustainability status rather than the absolute sustainability, i.e. deviations from a desirable level. While the measurement of relative sustainability is important for setting development priorities, absolute sustainability status has much more significance for its amenability to comparison over time. This study has, therefore, developed a framework for the measurement of agricultural sustainability in the Indian part of the Indo-Gangetic Plains, i.e. Haryana and Punjab. The dimensions captured are natural resources, ecological and economic.

Sustainability Indicator Framework

Identification of the indicators

The first and foremost step in the development of a framework is identification of relevant indicators for sustainable agriculture. These indicators were collected through an extensive review of literature. In the first stage, 144 indicators pertaining to soil, water, agro-biodiversity and economic efficiency were identified. Subsequently, the selected indicators were screened on broad criteria, namely relevance, measurability, and data availability. Two sets of procedures were used for screening the identified indicators. In the first step, four thematic workshops were organized for intensive discussion on each of the indicators. In the second step, cross-section opinion was sought by organizing a series of discussions with the multidisciplinary team of experts aimed to reduce the extent of overlapping and improve objectivity of indicators. In case of non-availability of data, proxy indicators or expert opinions were used. In total 79 indicators relating to soil health (15), water availability and quality (17), biodiversity, environment and climate change (22), and socio-economics (25) were selected. The broad area-wise number of selected indicators is given in Table 1. The selected indicators represent the *state* (condition) of affairs, *pressures* on the sustainability as a result of human interventions, and the *response* indicators of interventions to promote the sustainability.

Normalization of the indicators

The indicators selected have different units of measurement and scales, and thus require normalization to transform them into a common scale for developing a common indicator. Therefore, the next step is conversion of actual values of the indicators into a normalized score. Several methods of normalization are available serving different purposes and suitable to different data properties and important among these are min-max, benchmark and z-score. In this study, the values were normalized using min-max and benchmarking methods. The purpose of min-max normalization was to assess the relative sustainability. The most common example of this method of normalization is the Human Development Index (UNDP, 1995). A similar method was used in India for capturing the sustainability dimensions for research prioritization work in India (Mruthyunjaya et al., 2003). The benchmarking method gives deviation from the absolute sustainability as the indicators are normalized with reference to a pre-determined sustainability threshold value (Chand et al., 2015).

Table 1. Domain-wise number of indicators selected

Domains	Number of indicators
Climate extremes, vulnerability and emissions	9
Soil bio-physical properties and nutrient status	8
Diversity (crop/enterprises, insect/pest and microbe)	8
Productivity, efficiency and scale of operation	8
Water availability and degradation	7
Markets, institutional, programmes and policies	7
Terrestrial ecosystem and land use	6
Biodiversity conservation	4
Income, employment and nutritional security	4
Soil degradation	3
Water use efficiency	3
Equity/inclusiveness	3
Agrochemical application, and organic farming	3
Soil health improvement	2
Water policies, programmes and governance	2
Insect, pest and weed infestation threats	2
Total	**79**

Construction of composite index

Normalized indices are combined to construct a composite index by using a weighting scheme. The composite index was constructed by assigning both equal and differentiated weights. The unequal weights were assigned using the budgetary method and Principal Component Analysis (PCA). Further, the weights to the four dimensions, i.e. soil, water, agro-biodiversity and socio-economics, were assigned based on experts opinion. The PCA-weights were used to reduce the risk of double weighting, which may occur in case of equal weighting method (Yeheyis et al., 2013). PCA is also valuable in reducing large number of indicators to a manageable level.

Finally, Composite Agricultural Sustainability Index (CASI) using all the four dimensions was constructed by using additive and multiplicative methods. While additive aggregation is simple and widely used, the assumption of no synergy or conflict between indicators seems unrealistic in many situations. Therefore, the multiplicative aggregation was also used. Sensitivity analysis was also done to know the sensitivity of inclusion or exclusion of indicators, weights assigned to different indicators, and normalization procedures on composite index.

Data sources

The necessary data were collected from various published and unpublished sources. The major data sources were the *State Statistical Abstracts* of Punjab and Haryana and other government publications. For some of the qualitative indicators, experts were asked to assign the score on a scale of zero to ten. There are 44 districts in Haryana and Punjab, but for convenience, the analysis was done by merging the newly created districts after 2005 into the district from which these were carved out. For most of the indicators, the data pertain to triennium ending 2016-17.

Results

The sustainability index for different districts assigning equal weights and using two normalization procedures (min-max and benchmark) revealed that agriculture is moderately sustainable in both the states with an index value of around 0.5 (Figure 1). There were wide inter-district variations in the index ranging from 0.45 to 0.59 in Haryana and 0.47 to 0.56 in Punjab (Figure 1b). The variation was further higher in the index estimated using min-max method (Figure 1a). In Haryana, north eastern districts of Panchkula, Ambala, Yamunanagar and Karnal were the most agriculturally sustainable districts, while Rewari, Panipat, Sonipat and Mahendragarh were comparatively unsustainable. In Punjab, Faridkot, Mansa and Moga were the bottom-ranked districts, whereas Gurdaspur, Rupnagar, Sri Muktsar Sahib and Kapurthala have better sustainability index. By and large sub-mountainous districts were relatively better in terms of agricultural sustainability.

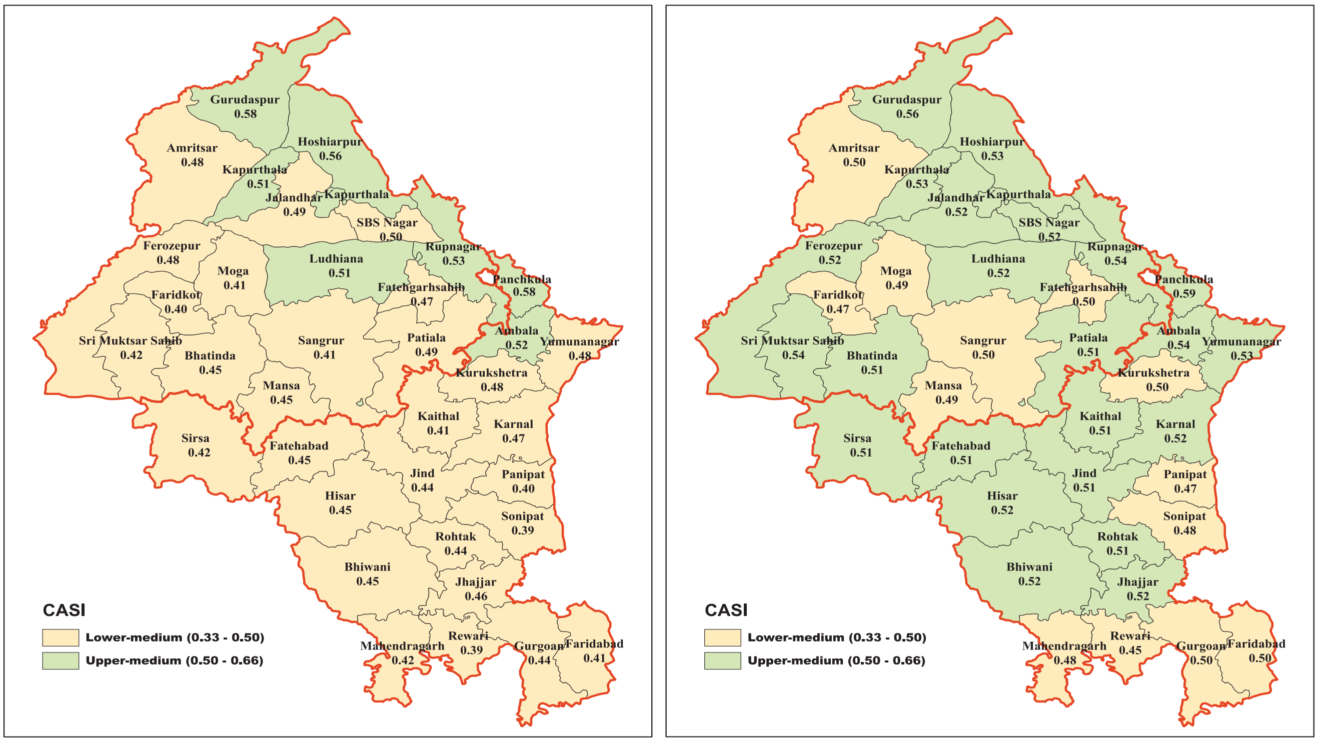
The composite indicators for both the states computed using different normalization methods, weighting schemes and aggregation procedures are given in Table 2. The average scores of absolute sustainability measured using the benchmark method of normalization were significantly higher than the relative sustainability index computed using the min-max method. In some districts, the differences were more than 25 per cent, notably in Punjab. Also, the substantial changes in ranking of districts of states were observed under two methods of normalization. However, different weighting methods did not make any difference in estimated values of the indices. Hence, it can be inferred that with an increase in the number of indicators, equal weights are as good as the endogenous weights (weights based on statistical methods). The sensitivity analysis, carried out by removing highly correlated indicators, revealed that the index value did not change significantly. Though insignificant but the differences were noticed under different aggregation techniques. A comparatively higher value of the index in arithmetic aggregation was due to its intrinsic nature of compensation of poor performer dimension by the high value of other dimensions.

The comparison of different dimensions of sustainability in the region revealed that the environment and water were the poorest among all the four dimensions (Table 3; Figure 2). The average value of Agrodiversity and Environmental Sustainability Index (ADESI) remained below 0.40 in both the states. Except for six

Table 2. Composite Agricultural Sustainability Index

Normalization method	Aggregation and weights	Haryana		Punjab	
		With all Indicators	After removing correlated indicators	With all Indicators	After removing correlated indicators
Min-Max	LAEW	0.47	0.47	0.48	0.48
	GAEW	0.46	0.47	0.48	0.48
	PCAW	0.46	0.46	0.47	0.48
	EXW	0.47	0.46	0.49	0.49
Benchmark	LAEW	0.52	0.49	0.52	0.49
	GAEW	0.51	0.48	0.51	0.48
	PCAW	0.51	0.48	0.52	0.49
	EXW	0.50	0.48	0.52	0.50

LAEW, Linear aggregation with equal weights; GAEW, geometric aggregation with equal weights; PCAW, geometric aggregation with PCA weights; EXW, linear aggregation with expert weights.



(a) Min-max normalization

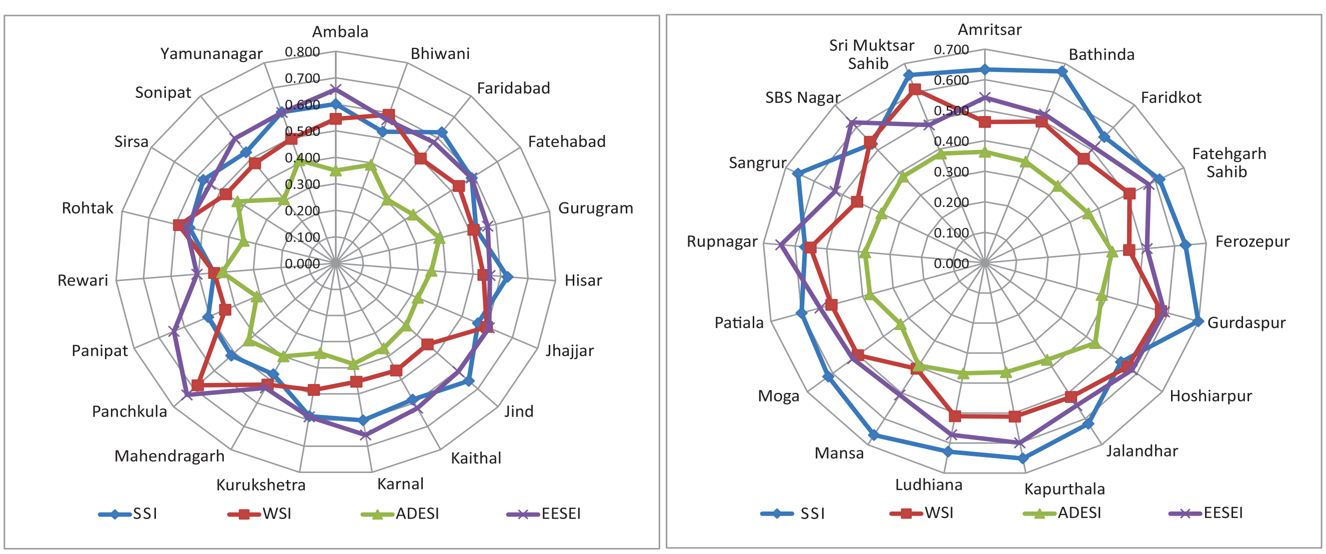
(b) Benchmark normalization

Figure 1. Composite Agricultural Sustainability Index

districts (4 in Haryana and 2 in Punjab), none of the districts could score ADESI above 0.40 (Figure 2). The districts of Faridabad, Jhajjar, Panipat, Sonipat and Moga need special attention to improve ecological aspects of sustainability. Similarly, the WSI was also low in the region with relatively higher inter-district variability. Nine districts in Haryana and six districts in Punjab scored Water Sustainability Index (WSI) below 0.5. The performance of this dimension was particularly weak in Punjab. Largely, the districts better in socio-economic dimension were relatively poor in soil health and environmental dimensions, while water and socio-economic dimensions were found to be positively correlated. Within each dimension, specific indicators requiring special care were identified.

Table 3. Indices of agricultural sustainability in Haryana and Punjab

	Haryana	Punjab
Soil Sustainability Index (SSI)	0.58	0.63
Water Sustainability Index (WSI)	0.53	0.51
Agrodiversity and Environmental Sustainability Index (ADESI)	0.35	0.38
Economic Efficiency and Social Equity Index (EESEI)	0.60	0.55
Composite Agricultural Sustainability Index (CASI)	0.52	0.52



(a) Haryana

(b) Punjab

Figure 2. Performance of districts across sustainability dimensions

Soil Sustainability Index

The current state of soil health was found to be moderately sustainable, the indicators putting pressure on soil sustainability were imbalanced use of fertilizers and high use of pesticides, which scored extremely low. The index values of response variables, i.e. area under conservation agriculture and application of organic manure, were also not encouraging, which underscores the need for an action to improve these indicators. Nutrient deficiencies, particularly phosphorus and organic carbon, are the emerging threats to agricultural sustainability in this region. The indicators of soil sustainability were relatively better in Punjab as compared to Haryana. The districts with light soil in Haryana need special focus in this regard.

Water Sustainability Index

Contrary to soil, water sustainability status was relatively better in Haryana (WSI 0.53) as compared to Punjab (WSI 0.51). The water sustainability was low due to extremely low value of indicators pertaining to groundwater extraction and management. Despite continuous depletion of groundwater, the area under micro-irrigation is very less in these states, particularly in Punjab. Though substantial area is under micro-irrigation in Haryana, it is mainly concentrated in the western districts. Low rainfall (<400 mm) coupled with a large area under irrigated paddy, are the major reasons of poor performance of the districts of Punjab. In Sangrur and Patiala districts, more than 87 per cent of the net sown area is under paddy. Poor management of drainage and poor quality of irrigation water are other causes of concern in these states.

Agro-Diversity and Ecological Security Index

This dimension (ADESI) measures the extent of diversity in agriculture, its vulnerability to climate change, and preparedness for minimizing climatic risks. The environmental dimension was not very encouraging in both the states. The average value of the index was 0.35 and 0.38 in Haryana and Punjab, respectively. The index barely crossed 0.40 in all the districts of Punjab, and Faridabad, Jhajjar, Panipat and Sonipat in Haryana. The inadequate area under forest, agro-forestry and perennial habitats , high GHG emission owing to large area under paddy and higher livestock population, less area under leguminous crops, and less area under organic farming were the major causes of concerns in these districts.

Socio-economic Index

As expected, socio-economic sustainability (EESEI) of the region was the strongest among all the four dimensions. However, a wide variability (ranging from 0.51 to 0.74 in Haryana and 0.46. to 0.65 in Punjab) was observed across the districts. Performance of the districts on the efficiency indicators was largely good except water productivity, but the poor performance was due to low value of some of the social indicators like the inadequate area under common property resources, poor social capital (SHGs, cooperatives, FPOs), etc. The study found that there is a scope for improving productivity of livestock in the region. High power subsidy is dragging down the performance of the districts of Punjab in this dimension. Rewari, Mahendargarh and Sirsa districts of Haryana, need special attention for improving the EESEI. In Punjab, EESEI was poor in Sri Mukatsar Sahib, Faridkot and Mansa.

Policy Implications

This brief presents a framework for measurement of sustainability of agriculture, capturing the dimensions of bio-physical, agro-biodiversity and socio-economics. The framework is applied to the north-west plains comprising Haryana and Punjab. The composite index showed a moderate level of agricultural sustainability in Haryana and Punjab (CASI 0.52). The sustainability indices for socio-economic and soil-related indicators were comparatively better and environmental and water dimensions of the sustainability were the most eroded dimensions, needing special attention. The results have two major implications. Firstly, there is an urgent need to adopt district-specific cropping pattern based on natural resource availability and improve the efficiency of the production, by adoption of better technology and conservation practices. Secondly, the response variables like high investment in R&D, irrigation efficiency, drainage, etc., need special attention. Increasing efficiency of input and resources like increasing area under conservation agriculture, promotion of agro-biodiversity, and diversity of production systems, should be given high priority. In some cases, policy correction like targeting subsidy can lead to better sustainability outcomes. The framework has a potential for its application in other parts of the country. It would require concerted efforts to capture data on a large number of indicators periodically, particularly on agro-diversity indicators. Emphasis should be given on assessing the sustainability trends with relevant indicators feasible in terms of implementation and responsiveness.

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