Composite index for measuring sustainability of food systems in Punjab

*Abdul Nasir, M. S. Toor and Kamal Vatta**

The present study makes an attempt to develop a composite index to measure sustainability of food systems. By assuming three components of food systems, namely availability, access and utilization, the data were utilized on 19 indicators pertaining to these components over the period 1970–71 to 2009–10. The values of overall index showed a marked and continuous improvement in the sustainability of food systems in Punjab. Still about one-third of the districts showed the potential for improving the availability component and the access to food could be improved in one-fifth of the districts of the state. While the availability can be improved by reducing the yield gaps, generation of additional employment opportunities can help in increasing access to food through enhanced incomes. Improvement in literacy and health services will also improve the utilization of food.

Keywords: Access and utilization, agriculture, availability, food systems, sustainability index.

SOUTH ASIA, the most densely populated region in the world, is afflicted with the problem of food scarcity, malnutrition and food insecurity. Approximately 46% of the world's poor, surviving on less than US$ 1 per day, live in this region and 51% of its population is food-energy deficient[1,2]. This situation is expected to worsen further with the population of the region expected to double from 2.7 billion in 1990 to 5.4 billion by 2030, causing a significant increase in the food requirements. The growth in rice and wheat production has outpaced the population growth due to significant jump in the productivity as a result of the success of the green revolution[3]. The recent stagnation in productivity, area under cultivation and sharp rise in input prices have squeezed the farm profits. The small and marginal farmers as well as the landless households, being the net buyers of the farm produce, have been the worst-hit segment of rural population. The food production and consumption system is placed at the heart of the sustainability debate, because it directly relates to the issues that are identified by the sustainability agenda such as the use of natural resources, impact on the environment, adverse impacts of intensified production, wasteful consumption patterns, poverty and global trade. The sustainability agenda has become an important driving force for change in the food production and consumption systems.

The paradoxical situation in India is that despite the highest levels of food production of 257 million tonnes (mt) during 2011–12 and the national stocks of foodgrains reaching as high as 66 mt during February, 2013, the country has performed poorly with respect to the hunger situation. More than 43% of the children under 5 years of age are underweight and despite a slight improvement in the hunger index in India from 24.2 in 1990 to 22.9 in 2012, the country ranked 65 out of 79 countries for which such estimates were prepared. Such a situation warrants that the food security need not only to be assessed from the point of view of availability of food but also from its affordability, accessibility as well as utilization. The food security problem must also focus on the aspects of poverty and sustainability[4].

Food systems and sustainability

The food systems consist of a chain of activities which connect food production, processing, distribution, consumption and waste management. The food security comprises three broad components of availability, access and utilization of food which further consist of many subcomponents. Their sustainability is not only determined by the increased production but also by their enhanced access as well as utilization. Sustainability aims at meeting the current needs without compromising the needs of the future generations and its measurement is used as a quantitative basis for its informed management. The metrics used to measure sustainability (sustainability of environmental, social and economic domains; individually as well as in various combinations) are evolving over time and include indicators, benchmarks, audits, sustainability standards and certification systems, indices and accounting, as well as assessment, appraisal and other reporting systems. They are applied over a wide range of spatial and temporal scales.

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The measurement of sustainability of food systems is important since it helps in achieving the long-term goals of the society to preserve natural resources while ensuring food security to the current population. It is now widely agreed that there are different dimensions of sustainability ranging from the biophysical dimensions to economic and social dimensions. The biophysical dimensions of sustainability relate to the long-term maintenance or enhancement of productive capacity of the resource base. The economic and social dimensions relate to the long-term economic viability of farming and rural communities. The purpose of sustainability assessment is to provide decision-makers with an evaluation of global to local integrated nature–society systems in short- and long-term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make society sustainable[5].

There are a number of frameworks of sustainability assessment that evaluate the performance. Indicators and composite indicators are increasingly recognized as a useful tool for policy making and public communication in conveying information on performance in fields such as agriculture environment, economy, society or technological development. The need for an integral systematic approach for the definition and measurement of an indicator is recognized in order to give well-structured methodologies that are easy to reproduce and to assure that all important aspects are included in the measurement.

In the above context, the measurement of food sustainability is essential for policy implication and for the assessment of food security of any region. The present study intends to construct a composite index to measure the sustainability of food systems in the food-surplus state of Punjab. The state was selected on the basis of data availability on different indicators for constructing the sustainability index.

Analytical framework

The food systems are supposed to consist of three main components, namely food availability, access to food and utilization of food. These components are further influenced by a number of sub-components. The food availability is determined by production, distribution and exchange mechanism of food, while access to food depends on affordability, allocation and preference. Further, utilization is determined by nutritional value, social value and food safety. In a nutshell, the food system can be broadly summarized as shown in Figure 1.

Any index of sustainability, thus, should take into consideration all the above parameters in order to be reliable. The significance of three broad components and their sub-components in the overall sustainability of the food systems depends on the region-specific characteristics and any component should take all this into consideration. The composite index of this study considers all the above components of food systems in Punjab.

Database and methodology

The study is based on the secondary data on various indicators of sustainability for all the districts of Punjab for the period 1970–71 to 2009–10 from the official publications (Statistical Abstract of Punjab) of the Economics Advisor to the Government of Punjab. In all, 19 variables were taken for developing the sustainability index (Table 1).

The composite index was developed using the methodology of Iyengar and Sudarshan[6]. This method is simple and it does not have the restrictive assumption of linearity in relation to indicators. Further, it provided for the classification of the districts based on the probability distribution of the sustainability index. This methodology was developed to work out a composite index from multivariate data and was used to rank the districts in terms of their economic performance. The methodology was well suited for the development of composite index of sustainability. It is assumed that there are m districts, k components for sustainability and X_{iK} is the value of the Kth component for the ith district ($i = 1, 2, 3, \ldots, m$; $K = 1, 2, 3, \ldots, k$). First, these values of sustainability indicators which are in the different units of measurement are normalized. When the observed values are related positively to sustainability, the standardization is achieved employing the formula

$$y_{iK} = \frac{x_{iK} - \text{Min } X_{iK}}{\text{Max } X_{iK} - \text{Min } X_{iK}}.$$

When the observed values are negatively related to sustainability, the standardized values are computed using the following formula

$$y_{iK} = \frac{\text{Min } X_{iK} - x_{iK}}{\text{Max } X_{iK} - \text{Min } X_{iK}}.$$

In this way, the standardized values for all the indicators of sustainability throughout the whole period 1970–71 to 2009–10 is achieved, which ranged between 0 and 1. The

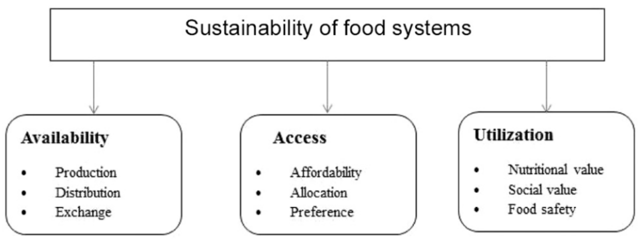

Figure 1. Summary of food system. (Source: Ericksen[7].)

Table 1. Various indicators of sustainability of food systems

Indicators of food availability	Indicators of access to food	Indicators of food utilization
Cropping intensity	Number of milch animals per thousand population	Literacy rate
Combined productivity of rice and wheat (kg/ha)	Number of non-workers per thousand population	
Population density per km^2	Number of marginal workers per thousand population	
Gross irrigated area as percentage of total cropped area	Number of main workers per thousand population	
Net irrigated area as percentage of net area sown	Number of agricultural labourers per thousand population	
Fertilizer consumption (tonne/ha)	Number of small farmers per thousand population	
Per capita food production (kg)	Number of marginal farmers per thousand population	
Total cropped area per thousand population	Total number of farmers per thousand population	
	Percentage of rural population	
	Work rate	

next step is to give weights to the standardized values of the indicators using the following formula

$$\bar{y}_{\mathrm{d}} = \sum_{i=1}^{m} w_i y_{id},$$

where ws $(0 < w < 1$ and $\sum wi = 1)$ were the determined weights given by

$$w_i = \frac{k}{\sqrt{\mathrm{var}(y_i)}},$$

$$k = \left[\sum_{i=1}^{n} \frac{1}{\mathrm{var}(y_i)}\right]^{-1}.$$

The weights were obtained for overall sustainability and for each component such as availability, access and utilization and the respective weights were multiplied with the standardized values and final indices were obtained for sustainability, availability, access and utilization. The choice of the weights in this manner ensured that large variation in any one of the indicators did not unduly dominate the contribution of the rest of the indicators and distort inter-district comparisons. For classification purposes, simple ranking of the districts would have been enough. However, for a meaningful characterization of the different stages of sustainability, suitable fractile classification from an assumed distribution is needed. One probability distribution which is widely used in this context is β-distribution. This distribution is defined by

$$f(z) = x^{a-1}(1-x)^{b-1}/b(a, b),\ 0 < x < 1 \text{ and } a, b > 0.$$

This distribution has two parameters a and b which can be estimated by comparing the following two equations

$$(y - m)a - mb = m - y,$$

$$(1 - y)a - yb = 0,$$

where y is the mean of district indices

$$m = sy^2 + y^2,$$

and sy^2 is variance of district indices. After obtaining the values of a and b, they are distributed with 20% interval and finally five classes are obtained and districts were ranked accordingly: (i) least, if $0 < y_d < z_1$; (ii) less, if $z_1 < y_d < z_2$; (iii) moderate, if $z_2 < y_d < z_3$; (iv) high, if $z_3 < y_d < z_4$ and (v) higher, if $z_4 < y_d < 1$.

Trends in overall sustainability of food

There has been a continuous increase in the overall index of sustainability from 0.469 in 1970–71 to 0.622 in 2009–10. With almost no increase between 1970–71 and 1975–76 (Figure 2), the index increased significantly to 0.502 in 1980–81 and the trend continued till 1990–91, when it reached 0.578. After a small decline in the index value from 1990–91 to 1995–96, it again increased continuously to 0.622 till 2005–06. The value stagnated at 0.622 again in 2009–10. In a nutshell, there was a vibrant improvement in the sustainability in food systems of Punjab during 1970–71 to 2009–10 owing to the tremendous success of the green revolution which not only increased the production and productivity but also improved access and utilization by improving the household income as well as literacy over time.

The decadal compound growth rate and variation in overall sustainability of food in Punjab is given in Table 2. During 1970s, Punjab grew significantly at the rate of 0.84% per annum in terms of sustainability index and coefficient of variation was 2.75, showing a higher variation and inconsistency. During 1980s, there was significant growth in the index and it improved by 1.10% per annum and the coefficient of variation increased thereby making the scenario of sustainability more inconsistent. The growth in 1990s was not significant and comparatively less and was only 0.09% per annum. The coefficient of variation was also comparatively less (0.92). During 1990s, the reason for less growth was mainly because of the decline in the access component of the food systems. During 2000s, the growth improved in comparison to 1990s but still was less than that during the 1970s and 1980s. The annual growth over the whole period was calculated as 0.83%, which showed that sustainability had

Table 2. Growth and variation in sustainability index in Punjab, 1970–71 to 2009–10

Year	Compound growth rate	t-value	Coefficient of variation
1970–71 to 1979–80	0.84**	5.11	2.75
1980–81 to 1989–90	1.10**	5.10	3.51
1990–91 to 1999–00	0.09[NS]	0.83	0.92
2000–01 to 2009–10	0.71**	6.75	1.77
1970–71 to 2009–10	0.83**	20.03	9.47

**Significant at 5% level. [NS]Non-significant.

Table 3. Trends in overall sustainability of food systems in various districts of Punjab

District	1970–71	1975–76	1980–81	1985–86	1990–91	1995–96	2000–01	2005–06	2009–10
Hoshiarpur	0.373	0.309	0.381	0.446	0.466	0.469	0.489	0.518	0.508
Gurdaspur	0.408	0.403	0.406	0.476	0.504	0.537	0.529	0.508	0.514
Rupnagar	0.427	0.373	0.409	0.456	0.520	0.517	0.547	0.608	0.563
Amritsar	0.487	0.484	0.495	0.557	0.576	0.590	0.603	0.597	0.571
Jalandhar	0.477	0.470	0.506	0.562	0.570	0.561	0.589	0.594	0.597
Ferozepur	0.491	0.492	0.524	0.593	0.620	0.607	0.625	0.611	0.620
Kapurthala	0.454	0.468	0.509	0.573	0.592	0.592	0.620	0.625	0.626
Mansa	*	*	*	*	*	0.589	0.641	0.624	0.631
Patiala	0.526	0.526	0.578	0.600	0.623	0.592	0.610	0.636	0.635
Moga	*	*	*	*	*	0.576	0.583	0.635	0.644
Bathinda	0.528	0.513	0.533	0.568	0.575	0.575	0.605	0.639	0.645
Faridkot	*	0.471	0.503	0.561	0.594	0.485	0.544	0.649	0.655
Ludhiana	0.516	0.544	0.579	0.616	0.623	0.608	0.641	0.666	0.658
Fatehgarh Sahib	*	*	*	*	*	0.612	0.618	0.665	0.662
Muktsar	*	*	*	*	*	0.555	0.587	0.653	0.664
Sangrur	0.534	0.569	0.599	0.626	0.650	0.633	0.670	0.702	0.670
Nawanshahr	*	*	*	*	*	0.535	0.574	0.678	0.684

*Districts were not formed at that particular period.

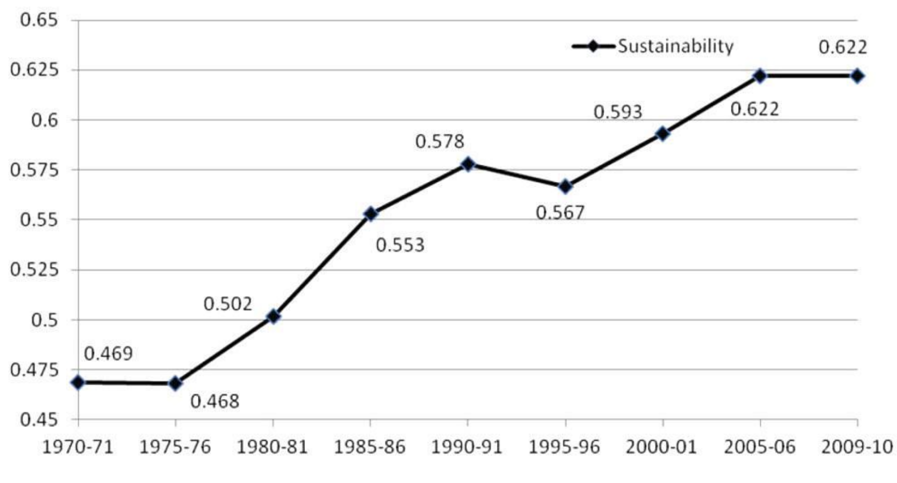

Figure 2. Trends in overall sustainability index in Punjab, 1970–71 to 2009–10.

improved significantly in Punjab, but the coefficient of variation was calculated as 9.47, which was very high showing large inconsistency.

Trends in sustainability across various districts

Table 3 shows that Hoshiarpur and Gurdaspur started as the least sustainable districts in 1970–71 and became less sustainable districts in 2009–10. The sustainability in these districts had very less improvement in comparison to some other districts which were ranked higher in 2009–10. Rupnagar and Amritsar also started as least sustainable districts, but improved relatively and ended as moderate sustainable districts in 2009–10. Jalandhar, Ferozepur, Kapurthala and Faridkot started as least sustainable districts and became higher sustainable districts

Table 4. Growth in overall sustainability of food systems in various districts of Punjab

District	1970–79	1980–89	1990–99	2000–09	1970–2009
Nawanshahr#	*	*	1.12**	2.04**	2.08**
Rupnagar	0.82NS	1.88**	0.20NS	0.13NS	1.35**
Muktsar#	*	*	0.21NS	1.87**	1.27**
Hoshiarpur	–0.08NS	1.59**	0.46NS	0.79**	1.14**
Kapurthala	1.18**	1.56**	0.22NS	0.17**	0.95**
Gurdaspur	0.55**	0.96NS	0.22NS	–0.34NS	0.89**
Moga#	*	*	–0.45**	1.17**	0.88**
Faridkot#	1.52**	1.10**	–1.30**	2.50**	0.79**
Ferozepur	1.10**	1.35**	0.34**	0.17NS	0.77**
Fatehgarh Sahib#	*	*	0.01**	0.80**	0.74*
Jalandhar	0.69**	1.15**	–0.03NS	0.20NS	0.70**
Mansa#	*	*	1.51**	0.17NS	0.67**
Amritsar	0.49**	1.36NS	0.24NS	–0.44**	0.65**
Bathinda	0.30NS	0.63**	–0.11NS	1.07**	0.63**
Ludhiana	1.09**	0.66**	0.12NS	0.34**	0.60**
Sangrur	1.05**	0.75**	0.24**	0.05NS	0.59**
Patiala	1.12**	0.58**	–0.30NS	0.67**	0.49**
Over all	0.84**	1.10**	0.09**	0.71**	0.83**

**Significant at 5%. NSNon-significant. *The estimates were not available as the district was a part of a previously existing one and was carved out as a separate district in the later years.

in 2009–10, except Jalandhar, which was classified as high sustainable district. Patiala, Bathinda, Ludhiana and Sangrur started in 1970–71 as less sustainable districts and ended as higher sustainable districts in 2009–10. Some of the districts like Moga, Mansa, Fatehgarh Sahib, Muktsar and Nawanshahr were formed in 1990s. From these new districts, Moga, Mansa and Fatehgarh Sahib started as high sustainable districts in 1995–96 and ended as higher sustainable districts in 2009–10, while Muktsar and Nawanshahr started as moderate sustainable districts in 1995–96 and ended as higher sustainable districts in 2009–10. Some districts which were newly formed in 2000s like Tarn Taran, Barnala and S.A.S. Nagar were excluded from this section, while their contribution to sustainability of food in Punjab was included. The trend in sustainability of food has not been uniform in all districts of Punjab. Some of them improved and were classified as higher sustainable districts and some were still less sustainable districts.

Growth in overall sustainability of food systems

This section deals with the decadal growth in sustainability of food systems in various districts of Punjab. The state has achieved a compound growth of 0.83% throughout the period from 1970–71 to 2009–10, but the scenario was not similar across all the districts of Punjab (Table 4). Some districts achieved growth relatively more than 0.83% while some were below this figure. As stated earlier, for some of the districts (Barnala, Tarn Taran and S.A.S. Nagar) individual sustainability status was excluded from this section because of their formation in 2000s, though their contribution to the state was not neglected. Among all the 17 districts, Nawanshahr which was given the status of a district in 1995, has achieved higher growth over the study period in Punjab; it achieved a growth of 2.08% which was more than twice the growth achieved by Punjab as a whole. Rupnagar had annual growth of 1.35%, though in the last two decades the growth has been less. However the district is still maintaining second position in Punjab. Muktsar had a growth of 1.27% over the period, having third position in Punjab. Hoshiarpur, Kapurthala, Gurdaspur and Moga had annual growth of 1.14%, 0.95%, 0.89% and 0.88% respectively, over the period. The above-mentioned districts had higher growth than the average growth of Punjab (0.83%). Faridkot achieved a growth of 0.79% per annum over the period, though it had a negative growth rate from 1990 to 1999. Ferozepur had an annual growth of 0.77% over the period, though in last two decades the growth has not been up to the mark. Fatehgarh Sahib and Jalandhar had an overall growth of 0.74% and 0.70% respectively, from 1970–71 to 2009–10. Mansa attained a growth of 0.67%, though in the last decade its growth has been less. Amritsar achieved a growth of 0.65% per annum over the period; in the last decade its growth was negative in sustainability of food. Bathinda showed a growth of 0.63%, though it had negative growth from 1990–91 to 1999–2000. Ludhiana and Sangrur achieved a growth of 0.60% and 0.59% respectively. Patiala secured the least growth (0.49%) among all the districts of Punjab. There was a common trend in growth of all the districts from 1990–91 to 1999–2000 – very less growth in almost all the districts and negative growth in some districts.

Conclusions and future implications

Punjab is the food basket of India and its everlasting sustainability is important for the country. In the light of ever-increasing population, rising income and changing pattern of food consumption, there is a need to further strengthen the food systems in India, especially in food-surplus regions like Punjab. Sustainability of food systems increased in Punjab, but 30% of the districts (five districts) did not fall in the higher sustainability zone. Moreover, stagnation was seen in the sustainability of food systems in 2000s. Most of the districts which were highly sustainable in 2009–10, did not show growth which was up to the mark compared to those districts which were less sustainable in 2009–10. Moreover high variability in terms of sustainability was seen among the districts. So there is a strong need to target those districts which rank lower in sustainability. It can largely be done by strengthening the components of sustainability.

Despite a significant improvement in the availability of food systems in Punjab from being the least sustainable in 1970 to higher sustainability in 2009–10, there is significant space for enhancing the availability. Still 35% of the districts (six districts) did not fall in the higher availability zone. The food availability in these districts can be further enhanced by focusing on the sub-components of availability such as production of food crops, increasing crop productivity, cropping intensity, area under irrigation and fertilizer consumption. About one-fifth of the districts also showed the potential to improve in terms of access to food and this can be effectively achieved by generating more employment opportunities. The focus should also be on employing dairy activities. There also exists the potential to improve utilization of food by focusing on literacy and health services.

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