An analysis on agricultural sustainability in India

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Sustainability of agriculture is a matter of concern for various stakeholders. The challenges encountered by Indian agriculture are due to agro-climatic/environmental, social and economic dimensions. The sustainability strength comes due to vibrancy of these dimensions. In order to understand the regional and temporal dynamics of these dimensions, a state-level analysis of sustainability was made for two time-periods. The sustainability index estimation was based on the human development index methodology. Data for two time-periods, i.e. 2001 and 2011 were used to estimate the indices. The results revealed that in general, sustainability did not deteriorate over the reference period, although some states gained and some others lost in terms of change in the level of sustainability.

Keywords: Agricultural sustainability, human development index, sustainability index, state-level analysis.

AGRICULTURE in India is facing several challenges which together manifest into sustainability issues. The symptoms of agricultural instability are sub-optimal growth, absence of desirable profits and distraction or movement of farmers away from the sector. The causes lie in the depleting status of natural resources and socio-economic conditions of the farmers. Sustainable agriculture is the efficient production of safe, high-quality agricultural products in a way that protects and improves the natural environment, the social and economic conditions of the farmers, their employees and local communities, and safeguards the health and welfare of all farmed species[1]. Several frameworks and models on measuring agricultural sustainability have been proposed under various production ecosystems[2–4].

Therefore, it is inferred that sustainability in agriculture is a complex concept and there is no consensus among scholars about its dimensions[5]. Concerns about sustainability in agricultural systems centre around the need to develop technologies and practices that do not have adverse effects on environmental goods and services, are accessible to and effective for farmers, and lead to improvements in food productivity[5]. It is also acknowledged that sustainability in agricultural systems incorporates concepts of both resilience (the capacity of systems to buffer shocks and stresses) and persistence (the capacity of systems to continue over long periods), and addresses many wider economic, social and environmental challenges.

India has great diversity in agro-climatic zones with as many as 127 zones under five agro-ecosystems such as rainfed, arid, irrigated, coastal and hilly systems. However, data regarding various parameters that are used for sustainability are generally available for the administrative units such as districts and political boundaries of states, rather than natural boundaries such as watersheds or agro-climatic zones. The spatial and temporal changes in sustainability indicators would throw light on the diverse and complex issue of agricultural sustainability in India. Therefore, a comparison of the state-wise status of agricultural sustainability during two different periods within a time span of 10 years, viz. 2001 and 2011 has been made in this study. The prime objective of this study is to assess agricultural sustainability using the three-dimensional indicators at a considerable interval.

Methodology

The status and performance of agriculture can be measured by the growth rates of the sector over different periods or during a specified period. Similarly, the absolute value of output from the sector can be compared over a period. These will reflect some aspects of the status and progress of the sector. However, if a comparison has to be made between different states in a country like India, which has significant diversity in terms of agro-climatic situations, crops and other allied activities, parametric values that will reflect the integration of all these need to be taken into account. Agricultural sustainability assessment is one such measure that will indicate these concerns. In the pursuit of agricultural sustainability assessment, the first step would be to clearly identify the indicators for the same. Several authors have identified different sets of these indicators for the three-dimensional agricultural sustainability[6–11]. Rao and Rogers[12] proposed

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Table 1. Selected sets of variables for agricultural sustainability index

Economic variables	Social variables	Ecological variables
Productivity of food grains (kg/ha)	Community managed institutions (SHGs/ 10000 population)	Population density (#/sq. km)
		Forest cover (%)
Value of agriculture output (Rs/ha, crops only)	Area under marginal and small holdings (%)	Cropping intensity (%)
Per capita income (Rs/head)	Human development index (HDI)	Livestock density (per sq. km)
Female work participation rate (%)		Poultry (per sq. km)
		Groundwater draft (% of exploited and critical sources)

state-of-the-art methodology in environmental, rural livelihoods and agricultural sustainability assessments, and a framework for the assessment of agricultural sustainability. Several parameters for developing a three-dimensional agricultural sustainability index have been used earlier. Hatai and Sen[13] analysed the district-level sustainability indices in Odisha using a mix of economic, ecological and social indicators. This entails data requirements from both primary and secondary sources. Based on survey of the literature and availability of state-level data, the sets of variables shown in Table 1 were finally chosen for working out the agricultural sustainability indices. At the same time some indicators like soil health, area of degraded lands, level of mechanization, agricultural labour supply, etc. although important for sustainability, were not taken into account mainly due to lack of authentic disaggregated data.

The basis for selecting the indicators for the three-dimensional agricultural sustainability analysis was because of the specific importance, relevance, influence and inter-relationship of each of the selected indicators within the complex agro-economic, geographic and demographic environment across the states. All indicators were considered to have a positive influence on sustainability, except the area under small/marginal holdings, human population density, livestock density and groundwater status, which has a negative impact on sustainability. The indicator-wise details are as follows.

Productivity of food grains

Food-grain productivity will explain the economic independence of a particular family/region/state in terms of food, which is locally available. Hence this assumes an inevitable role while calculating the sustainability indices. Higher the productivity on a sustainable basis, higher will be the strength of the economic dimensions. This is measured in kilograms per hectare for the major food grains in a particular state.

Value of agricultural output

The earnings from agriculture are reflected by the value of agricultural output (Rs/ha). These were considered for both time-periods, viz. 2001 and 2011 at constant prices (2004–05 base year). Generally higher value indicates better economic sustainability and thus agricultural sustainability. The influence of this variable on agricultural stability and thus on rural poverty has been adequately established[14].

Per capita income

The average income of the people in a state is obtained by its gross domestic product divided by its population in a particular year. Although agricultural income by way of value of output is part of the per capita income, the other two sources of income at the macro level, like from industry and services sectors, are also part of the per capita income. Further at the country level, the share of non-agricultural income is almost 86% and hence per capita income indicator was also considered for the estimation. This was calculated for the two-periods points at constant prices (2004–05). The role of non-farm sectors besides agriculture in bringing down rural poverty has been well documented. Hence, this was included as one of the indicators for agricultural sustainability[15].

Female work participation rate

Employment level indicates the general status of a family/region or the health of a state, but female employment as measured by their work participation will indicate the strength of the economy, since women constitute half the population. Further, the empowerment of women by way of better employment or their participation as labour is a social development indicator that fits into the overall agricultural sustainability and thereby general economic growth in a developing country[16].

Community managed institutions

Self-help groups (SHGs) have gradually evolved as socio-economic revolutionary institutions in India. They have been playing a great role in micro finance that is handy for agricultural operations and non-farm sector. Besides this, SHGs have been playing a key role in rural

development. The number of SHGs per 10,000 population was thus taken to represent one of the social variables. SHGs engaged in development activities have the potential to empower their members through the provision of knowledge, skills, motivation and competencies that underpin sustainable agriculture[17,18].

Area under marginal/small holdings

Marginal and small farmers account for the majority of land holdings in India. The area owned/operated by them indicates the level of social equity and security. Hence the percentage agricultural land area held by this category of farmers was considered in the study. This was taken as a variable that may have negative influence on sustainability due to increase in the number of holdings on account of fragmentation and sub-division, making agriculture all the more sub-optimal in scale[19].

Human development index

Human development index (HDI) is a composite statistic of life expectancy, literacy and income indices used to rank countries. Hence, HDI was used under the social dimension of agricultural sustainability. This is a two-way indicator. It is both a causal and resultant indicator, as a better livelihood option, including agriculture, would result in a better HDI. On the other hand, with a better baseline HDI the impact on sustainability would also be better and hence the same was taken into account as a social dimension of agricultural sustainability[20,21].

Population density

The human population in any geographical area will indicate the demand and pressure on the ecological systems in that area. Therefore, the population density (number/sq. km) was taken as one of the ecological variables and as a negatively influencing variable on agricultural sustainability in the Indian context, since the country already has higher density (411 persons/sq. km in India compared to a mere 47 in the world as a whole).

Forest cover

Forests are the core biological systems that determine the health of dependent systems like agriculture by providing the much needed ecosystem services. Hence the area under forests as percentage of the geographical area was chosen as positively influencing agricultural sustainability[22].

Cropping intensity

The different types of crops grown in agriculture will indicate if there is balance and scope for withstanding the natural hazards and climate change. This is taken as the percentage of gross cropped area to the net cultivated area. It also indicates the pattern of crops over different growing seasons on the same piece of land. It takes into account crop diversity, balance and succession plan, and hence is considered as a positively influencing ecological dimension indicator for agricultural sustainability[23,24].

Livestock density

The livestock supplement and complement the cropping systems of agriculture. They provide the inputs to agriculture like manure and draft power on the one hand and also give food and nutrition to the farm families and other populations. On the other hand, livestock get the fodder and feed from the crop sector and thus go hand-in-hand to sustain agriculture in different ways. Therefore, the number of livestock per square kilometre was also taken as a variable in ecological dimensions. It will have negative influence after some level, since the pressure on natural resources increases due to the extensive nature of rearing of animals, which is the dominant pattern in Indian conditions[25].

Poultry

This is popular in Indian states predominantly as a backyard system and of late as commercial poultry farming. The former system is common in tribal and remote rural areas, whereas the latter has emerged as a supplementary and complementary enterprise in the last 3–4 decades. The feed for the birds is mainly nutritious cereals and millets like maize and sorghum, whereas poultry manure is an input for farming. The number of poultry birds per square kilometre was also taken as an indicator in addition to livestock density. The poultry stock was 2.2 birds/ha of geographical area in India, while the large and small ruminant livestock stands at 1.6 animals/ha according to the 2012 livestock census[26]. Based on body weight and the biological demand for feed/fodder, the demands of ruminants will be much higher. Hence, the poultry density indicator was taken as positively influencing agricultural sustainability at current levels.

Groundwater status

Groundwater is an important source for agriculture in several regions of India; almost 45% of irrigation is from this source. The Central Ground Water Board (CGWB) provides the status of groundwater draft annually, which is a fair indicator of the level of exploitation[27,28]. The percentage of critical and over-exploited sources in a given year across the states is considered as negatively influencing agricultural sustainability.

The method of sustainability index estimation adapted by Hatai and Sen[13] has been broadly used for the present study. This method is derived from the HDI calculation approach of UNDP[20]. Sustainability has to be measured on the scales of time and space, i.e. over a period of time and across geographical regions. At the same time, it has to be relative rather than absolute. The three-dimensional sustainability would include economic sustainability, social sustainability and ecological sustainability indices. To arrive at the respective components of the indices, the following protocol is used.

Let X_{ijk} and SI_{ijk} represent the value of the ith variable, jth component of the kth state and the index for the ith variable, jth component of the sustainability index (SI) of the kth state respectively. Accordingly, SI of the respective dimension will be

$$\mathrm{SI}_{ijk} = \frac{X_{ijk} - \mathrm{Min}_k X_{ijk}}{\mathrm{Max}_k X_{ijk} - \mathrm{Min}_k X_{ijk}}, \quad (1)$$

$$\mathrm{SI}_{ijk} = \frac{\mathrm{Max}_k X_{ijk} - X_{ijk}}{\mathrm{Max}_k X_{ijk} - \mathrm{Min}_k X_{ijk}}, \quad (2)$$

where i = variables 1, 2, 3, …, I; j = components 1, 2, 3, …, J; k = states 1, 2, 3, …, K.

Equation (1) was used for variables with positive implications for SI and eq. (2) was used for variables with negative implications on SI. In the case of population density, livestock density, groundwater status and area under small/marginal holdings, eq. (2) was used as these will have negative influence with increased values. After working out the SI for all variables, the indices for different components/dimensions (economic, social and ecological) were estimated as a simple mean of the indices for the respective variables as

$$\mathrm{SI}_{jk} = \sum_{i=1}^{I} \mathrm{SI}_{ijk},$$

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

In the next stage, all the three components/dimensions were pooled together by taking their simple mean. Since the strength of individual indicators in each of the three dimensions is reflected in the index values, the mean of the indices of three dimensions was taken to reflect the overall agricultural sustainability rather than assigning variable weightages. Thus, we get the state-wise SI. Thus sustainability indices for the major states of India were worked out. Since sustainability is not just a status at one point of time but generally over a period of time, two reference points were taken, 2000–01 and 2010–11, for estimating sustainability. On estimating the sustainability indices for the states, they were compared for differences using t test and the inferences were drawn accordingly.

Results and discussion

Growth rates and value of output

Agricultural growth rate that accounts for the incremental progress in the value pertaining to contribution from various sub-sectors of agriculture, is one of the indicators of the health of the sector. The overall growth rate of Indian agriculture was 2.79% per annum during 1996–97 to 2000–01 (first reference period), which increased to 3.89% during 2006/07 to 2010–11, which is the second reference period (Table 2). Across the states, Bihar had the highest growth rate in the first reference period (11.62%), while Rajasthan recorded the maximum growth rate in the latter period (9.42%). Some states had negative growth in the first reference period and positive values in the second period. Kerala had a unitary growth followed by a negative growth in the two respective periods. Only, Andhra Pradesh (undivided), Himachal Pradesh, Karnataka, Maharashtra and Uttar Pradesh had consistent positive growth, indicating vibrancy in the sector. In absolute terms (value of agricultural output at constant prices), the values increased by 12% in the second reference period compared to the first period pan India (Table 3). Gujarat, Jharkhand, Andhra Pradesh, Madhya Pradesh, Odisha, Himachal Pradesh, Chhattisgarh and Uttarakhand registered over 20% growth during 2001 to 2011. The per capita values, however, were the highest in Punjab followed by Haryana; they were over 20 times higher than the national average.

Table 2. Growth rate of agriculture across states in India: 1996/2011

State	Average growth/year (%)	
	1996/97–2000/01	2006/07–2010/11
Andhra Pradesh	5.11	5.06
Assam	–0.55	3.27
Bihar	11.62	6.14
Gujarat	–1.22	4.35
Haryana	2.8	5.01
Himachal Pradesh	3.09	2.93
Karnataka	3.18	6.41
Kerala	0.82	–2.69
Madhya Pradesh	–2.21	3.77
Maharashtra	2.26	6.22
Odisha	–1.58	3.62
Punjab	2.86	2.01
Rajasthan	1.13	9.42
Tamil Nadu	3.41	4.07
Uttar Pradesh	3.43	2.81
West Bengal	2.79	2.16
Jharkhand	2.75	6.6
Chhattisgarh	–7.13	6.77
Uttarakhand	2.02	3.42
India	2.79	3.89

Source: Authors' calculations from Planning Commission data, Government of India.

The growth rates and absolute values of figures for agricultural output give some indication of the comparative status, vividly reflecting the resource base and factor productivity. However, the different factors and their relative positions need to be understood to integrate the long-term sustainability of the sectors.

Sustainability

Tables 4 and 5 give the values of various indicators considered under three components of sustainability index for 2001 and 2011 respectively.

Ecological indicator

Among the major states for which the analysis was done, West Bengal, Bihar and Kerala had higher density of over 800 persons per square kilometre during 2001. Bihar overtook West Bengal with the highest population density by 2011.

Forest cover: In 2001, Uttarakhand, Chhattisgarh, Kerala and Assam had forest cover that is desirable according to the National Forest Policy (one-third of geographical area). On the other extreme, six states – Haryana, Rajasthan, Punjab, Uttar Pradesh, Bihar and Gujarat – had less than 10% of the area under forests during that year. Even after a decade in 2011, more or less similar situation prevailed, although there was a marginal increase in some states.

Table 3. Per capita annual average value of agricultural output (Rs 2004–05 prices)

State	1999–2000 to 2003–04	2006–07 to 2011	% Change
Andhra Pradesh	7312	10119	28
Assam	5540	5961	7
Bihar	3532	3398	–4
Gujarat	5993	9040	34
Haryana	11913	12793	7
Himachal Pradesh	8627	11029	22
Karnataka	7973	7845	–2
Kerala	7588	7024	–8
Madhya Pradesh	5472	7105	23
Maharashtra	6975	7685	9
Odisha	4962	6441	23
Punjab	15703	16184	3
Rajasthan	7004	8207	15
Tamil Nadu	4943	5683	13
Uttar Pradesh	5386	5935	9
West Bengal	7338	7541	3
Jharkhand	2465	3757	34
Chhattisgarh	5697	7247	21
Uttarakhand	6189	7870	21
India	6277	7169	12

Note. Estimates arrived based on secondary data of the planning Commission, GoI.

Cropping intensity: In 2001, the intensity of cropping was higher in states like Punjab, Haryana, West Bengal, Himachal Pradesh, Uttarakhand and Uttar Pradesh with over 150%. Higher intensity reflects efficient use of land area by covering the land with some crop or the other and using the available water in an efficient manner. This had significantly increased in the next ten years in these states and there was a general increase across the other states as well.

Livestock density: In 2001, the number of livestock per unit area (square kilometre) was highest in West Bengal followed by Bihar, Uttar Pradesh and Haryana. This situation slightly changed in the next ten years with Andhra Pradesh, Assam, Tamil Nadu and Jharkhand joining other states that have a density of 200 or above.

Poultry density: Poultry has two dimensions – backyard and commercial. The overall poultry population (number/sq. km) was higher in Kerala, Tamil Nadu and Andhra Pradesh during 2001, and the trend remained similar in 2011 too, with small gains.

Groundwater status: Groundwater level in an agricultural area indicates the net balance that is available after exploitation for agricultural and other uses, and the recouping by rainfall in that area and subsurface flow from other areas. Based on the data published by CGWB in the states for the two time-periods and the over-exploitation and critical nature categories of groundwater status, it can be inferred that the situation is alarming in Rajasthan, Punjab and Haryana, especially due to indiscriminate use in the last ten years. Several studies have also confirmed this observation[29,30].

Economic indicators

Productivity of food grains: During 2001 productivity of food grains was highest in Punjab followed by Haryana, Tamil Nadu and West Bengal. The same was lowest in Chhattisgarh followed by Maharashtra, Gujarat and Madhya Pradesh. By 2011, the trend was more or less similar, but the second place was taken by West Bengal.

Value of agricultural output: During 2001 the per hectare value of agricultural output (crops only) was higher in West Bengal, Kerala, Punjab, Himachal Pradesh, Uttarakhand and Haryana. By 2011, Himachal Pradesh took the first place due to greater value of horticultural crops grown there, while the remaining states retained their relative places.

Per capita income: Punjab topped the list with the highest per capita income followed by Haryana, Maharashtra, Himachal Pradesh and Tamil Nadu. Bihar and Uttar Pradesh had the least per capita income that was below Rs 10,000 per annum.

Table 4. Ecological, economic and social indicator values – 2001

State	Ecological variables						Economic variables				Social variables		
	Population density (#/sq. km)	Forest cover (%)	Cropping intensity (%)	Livestock density (per sq. km)	Groundwater status (% of critical and over exploited units)	Poultry (per sq. km)	Yield of food grains (kg/ha)	Value of agricultural output (Rs/ha, crops only)	Per capita income (Rs/head)	Female work participation rate (%)	Community-managed institutions (SHGs/10,000 population)	Area under marginal and small holdings	Human development index (HDI)
Andhra Pradesh	277	16	122	175	17	2122	2089	32,890	17,243	35	37	46	0.416
Assam	340	35	147	176	0	1567	1457	42,493	12,797	21	1	43	0.386
Bihar	881	6	141	288	3	512	1694	38,403	6,396	19	1	62	0.367
Chhattisgarh	154	42	112	100	0	606	589	9,947	10,985	40	34	34	0.288
Gujarat	258	8	111	110	33	376	827	17,675	18,392	28	3	25	0.479
Haryana	478	4	173	201	40	1533	3060	48,824	24,138	27	1	21	0.509
Himachal Pradesh	109	26	171	92	0	150	2189	58,537	22,495	44	15	51	0.488
Jharkhand	338	28	116	199	0	912	1095	23,319	10,294	26	3	45	0.274
Karnataka	276	19	118	134	9	999	1412	36,322	17,464	32	12	34	0.478
Kerala	819	40	137	90	6	3509	1812	69,013	19,917	15	7	75	0.638
Madhya Pradesh	196	25	122	116	1	329	945	13,918	11,862	33	2	26	0.394
Maharashtra	315	15	121	119	15	1033	757	25,695	22,992	31	3	40	0.523
Odisha	236	31	135	150	0	753	950	22,316	10,452	25	12	53	0.404
Punjab	484	5	176	171	67	1252	4031	59,455	27,865	19	0	8	0.537
Rajasthan	165	5	121	144	70	126	883	13,914	12,897	34	4	12	0.424
Tamil Nadu	480	167	120	192	44	3472	2461	42,371	20,927	32	16	56	0.531
Uttar Pradesh	690	6	150	243	3	200	2105	38,227	9,541	17	2	61	0.388
Uttarakhand	159	45	159	92	0	401	1712	52,921	15,482	27	24	55	0.415
West Bengal	903	12	168	469	18	1457	2231	72,049	16,521	18	4	78	0.472
India	324	21	131	148	15	1008	1626	30,964	16,648	25	7	39	0.472

Female work participation rate: In 2001, this was much higher (>30%) in Himachal Pradesh, Chhattisgarh, Rajasthan, Madhya Pradesh, Karnataka and Andhra Pradesh. In the next 10 years it increased significantly across all states and was highest in Andhra Pradesh with almost 63%.

Social indicators

Community-managed institutions: In 2001 Andhra Pradesh, Chhattisgarh, Tamil Nadu, Himachal Pradesh, Karnataka and Odisha had higher concentration of SHGs. The density of SHGs increased significantly by 2011 and states like Kerala picked up faster in this respect. In some states the number increased by over five times.

Area under small/marginal holdings: Small and marginal holdings are the lifeline of agriculture in India. However, due to sub-division of these holdings over the generations, repeated fragmentation is taking place and hence consolidation has become a distant vision. In states like West Bengal, Kerala, Bihar and Uttar Pradesh, the share of area owned by these categories of farmers was significantly higher in 2001 (>60%). The situation remained the same in the next 10 years in almost all the states.

Human development index HDI for the states varies between 0 and 1, with 1 being the highest. Among the states, Kerala was on the top in 2001, followed by Punjab. Jharkhand and Chhattisgarh were at the bottom of the table in this respect. By 2011, Kerala remained on the top, with Himachal Pradesh taking the second place. Uttar Pradesh slipped to almost the bottom of the table after Chhattisgarh.

Component indices

The indicator (variable)-wise indices were worked out for 2001 and 2011 as discussed earlier in the text. They were further used for estimating the component indices such as ecological index, economic index and social index. In 2001, ecological sustainability was highest in

Table 5. Ecological, economic and social indicator values – 2011

State	Ecological variables						Economic variables				Social variables		
	Population density (#/sq. km)	Forest cover (%)	Cropping intensity (%)	Livestock density (per sq. km)	Groundwater status (% of critical and over exploited units)	Poultry (per sq. km)	Yield of food grains crops (kg/ha)	Value of agricultural output (Rs/ha, crops only)	Per capita income (Rs/head)	Female work participation rate (%)	Area under marginal and small holdings	Community-managed institutions (SHGs/10,000 population)	Human development index (HDI)
Andhra Pradesh	308	17	130	219	18	2060	2294	44,140	40,366	63	55	173	0.473
Assam	398	35	148	220	0	1687	1662	51,215	21,406	26	49	79	0.444
Bihar	1106	7	137	322	1	376	1530	34,385	13,632	11	76	24	0.367
Chhattisgarh	189	41	121	107	10	988	1008	27,237	27,156	59	42	46	0.358
Gujarat	308	7	119	120	24	568	1560	38,994	52,708	48	30	32	0.527
Haryana	573	4	185	200	75	3249	3383	61,444	59,221	38	23	14	0.552
Himachal Pradesh	123	26	176	94	26	155	2246	105,822	47,106	68	54	77	0.652
Jharkhand	414	29	115	227	4	620	1330	63,546	21,734	26	43	26	0.376
Karnataka	319	19	124	161	43	1363	1377	39,452	39,301	53	40	92	0.519
Kerala	860	45	128	92	17	4373	1859	61,023	49,873	37	77	148	0.79
Madhya Pradesh	236	25	146	132	28	181	1285	24,384	22,382	45	34	21	0.375
Maharashtra	365	16	138	117	8	1801	1039	37,112	62,729	56	45	68	0.572
Orissa	270	31	116	148	0	893	1397	41,238	25,708	37	70	124	0.362
Punjab	551	4	190	147	83	1442	4144	71,778	44,752	35	9	15	0.605
Rajasthan	200	5	142	166	86	87	931	18,613	25,616	58	16	34	0.434
Tamil Nadu	555	18	116	237	52	4165	2477	48,141	51,928	56	61	131	0.57
Uttar Pradesh	829	6	153	250	26	145	2236	49,262	17,349	28	65	24	0.38
Uttarakhand	189	46	162	96	35	506	1780	61,843	44,723	60	64	44	0.49
West Bengal	1028	15	192	422	14	2304	2522	86,403	32,228	22	81	73	0.492
India	381	21	141	161	27	1225	1798	40,694	35,993	41	45	62	0.547

Uttarakhand, which ranked first followed by Himachal Pradesh, while it was least in Rajasthan (19th), in the list of 19 states. This indicates that variables like forest cover are significant in the states with higher ecological security and non-significant in the least indexed states. Further, variables like human and livestock population and groundwater exploitation reflect the ecological status especially when they are higher, as in the case of Bihar where higher population density is a negatively influencing variable and in the case of Rajasthan, where it is more due to groundwater exploitation. They have resulted in low ecological index in these states. Similarly, the economic sustainability index values for the states in 2001 indicated that Himachal Pradesh was at the top followed by Punjab. This was purely because of their dominance in agricultural productivity, value of output and per capita income. At the bottom of the list was Odisha followed by Bihar, the reasons for this being poverty-led backwardness. The social sustainability indices revealed that Andhra Pradesh was on the top followed by Punjab. Bihar and Uttar Pradesh were at the bottom of this social index (Table 6).

Similarly for 2011, the situation was assessed for all the three dimensions (Table 7). In respect of ecological sustainability, Uttarakhand was again at the top followed by Kerala. At the bottom of this list were Uttar Pradesh and Bihar. Economic sustainability was highest in Himachal Pradesh followed by Punjab. On the other hand, it was lowest in Bihar as in the case of 2001. In the case of economic sustainability, Himachal Pradesh replaced Punjab at the top position. Himachal Pradesh topped the list in social sustainability index with Kerala in the second place. Bihar, on the other hand, lagged behind the rest of the states even in this respect.

Overall agricultural sustainability indices

The overall agricultural sustainability was estimated as a mean of the three components of indices (ecological, economic and social) for the two reference years – 2001 and 2011. For 2001, Himachal Pradesh topped the list followed by Punjab. Bihar, Uttar Pradesh and Jharkhand were in the last three positions. Himachal Pradesh once

Table 6. State-wise agricultural sustainability – 2001

State	Ecological Sustainability		Economic sustainability		Social sustainability		Agricultural sustainability	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Andhra Pradesh	0.56	8	0.50	6	0.61	1	0.56	4
Assam	0.71	4	0.32	11	0.28	15	0.43	11
Bihar	0.35	18	0.22	18	0.17	19	0.25	19
Chhattisgarh	0.67	5	0.27	14	0.53	3	0.49	9
Gujarat	0.41	16	0.30	12	0.47	8	0.39	14
Haryana	0.51	13	0.65	3	0.50	5	0.55	5
Himachal Pradesh	0.74	2	0.75	1	0.41	11	0.64	1
Jharkhand	0.56	9	0.23	17	0.18	18	0.32	17
Karnataka	0.55	10	0.44	9	0.50	4	0.50	8
Kerala	0.72	3	0.48	7	0.41	12	0.54	6
Madhya Pradesh	0.59	7	0.26	16	0.38	13	0.41	12
Maharashtra	0.53	11	0.40	10	0.44	10	0.46	10
Odisha	0.65	6	0.21	19	0.35	14	0.40	13
Punjab	0.45	14	0.73	2	0.57	2	0.59	2
Rajasthan	0.33	19	0.27	13	0.49	7	0.36	16
Tamil Nadu	0.51	12	0.58	4	0.49	6	0.53	7
Uttar Pradesh	0.42	15	0.27	15	0.20	17	0.30	18
Uttarakhand	0.79	1	0.47	8	0.46	9	0.57	3
West Bengal	0.37	17	0.51	5	0.22	16	0.37	15

Table 7. State-wise agricultural sustainability – 2011

State	Ecological Sustainability		Economic sustainability		Social sustainability		Agricultural sustainability	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Andhra Pradesh	0.53	9	0.54	6	0.54	2	0.54	4
Assam	0.65	5	0.26	17	0.35	11	0.42	11
Bihar	0.29	19	0.09	19	0.05	19	0.14	19
Chattisgarh	0.66	4	0.31	12	0.25	13	0.41	12
Gujarat	0.45	15	0.47	9	0.41	9	0.44	10
Haryana	0.50	10	0.67	3	0.42	8	0.53	5
Himachal Pradesh	0.67	3	0.77	1	0.48	5	0.64	1
Jharkhand	0.50	11	0.27	15	0.22	17	0.33	17
Karnataka	0.48	12	0.41	11	0.48	6	0.45	9
Kerala	0.70	2	0.49	8	0.63	1	0.61	2
Madhya Pradesh	0.56	8	0.24	18	0.25	14	0.35	15
Maharashtra	0.60	6	0.51	7	0.44	7	0.52	7
Odisha	0.59	7	0.28	14	0.28	12	0.38	13
Punjab	0.45	14	0.67	2	0.53	3	0.55	3
Rajasthan	0.35	17	0.27	16	0.40	10	0.34	16
Tamil Nadu	0.47	13	0.60	4	0.50	4	0.52	6
Uttar Pradesh	0.34	18	0.28	13	0.11	18	0.25	18
Uttarakhand	0.70	1	0.56	5	0.24	15	0.50	8
West Bengal	0.45	16	0.46	10	0.23	16	0.38	14

Note: *t* test of overall sustainability index values across states for the two time-periods was non-significant. A statistical analysis of the two sustainability indices indicated that there was no difference in the sustainability indices across the states as a whole in the two points of time, although there was visible difference in some states like Bihar and Chattisgarh which showed decrease in the index values while in Kerala and Maharashtra there was a significant rise in the SI values during 2001–2011.

again bagged the top position in 2011 leaving the second and third position to Kerala and Punjab respectively. The last three positions were retained by the same states as in 2001.

Conclusion

The ecological, economic and social indices of various states in the Indian Union for two different time-periods

(2001 and 2011) with a gap of 10 years have been estimated and compared in this study. A methodology to calculate the overall agricultural sustainability index was developed. It was found that in 2001, Himachal Pradesh topped the list followed by Punjab. Bihar, Uttar Pradesh and Jharkhand were in the last three places. Himachal Pradesh bagged the first position in 2011 also. The second and third positions were occupied by Kerala and Punjab respectively. The last three positions were the same as in 2001. In general, sustainability across the studied 19 major states of India did not deteriorate during the 10-year period of reference, although concerns are emerging on account of indiscriminate exploitation of some natural resources that affect the agriculture sector in the long run. This indicates two things – either the reference period is inadequate, or the concerns of sustainability are probably unfounded, which need to be further studied.

Nevertheless this study was useful in assessing the status of Indian states in terms of their ecological, economic, social and agricultural sustainability and subsequently analysing the lacuna and constraints for lag in the developmental process. As a remedial measure, appropriate social, environmental and agricultural schemes and projects can be designed and implemented, wherever required.

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