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Agricultural Sustainability Status of the Agro-Climatic Sub-Zones of India: Empirical Illustration of an Indexing Approach

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Since the critical dimensions of sustainable development in general and sustainable development of agriculture (SDA) in particular are ecology, economics, and intra- and inter-generational equity (Barbier, 1989; Daly, 1990; Swaminathan, 1991), any approach for developing an indicator for SDA should necessarily reflect all these three dimensions. Unfortunately, the applicability and practical utility of the currently available approaches for evaluating SDA like the agro-ecosystem analysis (Conway, 1985), mathematical programming-based simulation (*e.g.*, Parikh, 1988), dynamic programming (Saleth, 1991), and 'carrying capacity' evaluation [Food and Agriculture Organization (FAO), 1984] are severely limited by their methodological inability to capture all the critical concerns of SDA, excessive data demand and limited transparency.

While the current information is not a match for the data requirements of sophisticated approaches, the easy availability of simple information on the ecological, economic and equity aspects of agriculture points to the need for an operational approach and an unifying framework for integrating such diverse set of data to develop an indicator for SDA which is simple, transparent and information-efficient, *i.e.*, the ability to generate policy relevant information within the currently binding information constraint. This paper aims to *(i)* expose the concept and methodology of the Sustainable Livelihood Security Index (SLSI) proposed by Swaminathan (1991) and operationalised by Saleth and Swaminathan (1992, 1993) and *(ii)* empirically illustrate the practical utility and policy relevance of SLSI as a litmus for evaluating the relative agricultural sustainability status of 80 agro-climatic sub-zones of India using easily available data.

I

CONCEPTUAL BASIS AND ANALYTICAL FRAMEWORK FOR SUSTAINABLE LIVELIHOOD SECURITY INDEX (SLSI)

The major goal of SDA in developing countries like India is to create and maintain livelihood security options (Chambers, 1986; Swaminathan, 1991; Chambers and Conway, 1992). The concept of Sustainable Livelihood Security (SLS) is defined by Swaminathan (1991) as livelihood options which are ecologically secure, economically efficient and socially equitable. The intimate conceptual and casual linkages between the SLS and other welfare goals like poverty alleviation, meeting basic needs, human development and quality of life (see Saleth and Swaminathan, 1993) justify SLSI as a legitimate indicator for SDA.

The analytical framework essential for operationalising SLS in the form of SLSI is identified by the following propositions about SDA: *(i)* given the three-dimensional conception of SDA, the necessary conditions for sustainability are ecological security, economic efficiency and social equity - both in intra- and inter-generational contexts - and *(ii)* given the dynamic and contextual nature of SDA, sustainability needs to be relative rather than

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absolute both in time and space.

In an operational context, the multi-dimensional conception of SDA requires the SLSI to be a composite of three indices, *i.e.*, Ecological Security Index (ESI), Economic Efficiency Index (EEI) and Social Equity Index (SEI), so that it can take stock of both the conflicts and synergy between ecological, economic and equity aspects of SDA. The relative nature of SDA requires the SLSI to be also relative, *i.e.*, the sustainability potential of any region should be contrasted with that of other regions or against some established norms or conventions (*e.g.*, the poverty line or minimum dietary requirement to obtain a relative picture. Since the contextual nature of SDA implies that the relative significance of the three components of SLSI varies by regions, there is a need for identifying suitable weighting scheme to assign component and regional-specific weights.

II

SLSI METHODOLOGY

The SLSI methodology is actually a generalisation of the relative approach underlying the Human Development Index developed by the United Nations Development Programme (UNDP) (1990). While the SLSI methodology is explained in detail elsewhere (see Saleth and Swaminathan, 1992, 1993), here, a brief outline is given. Let X_{ijk} and $SLSI_{ijk}$ denote respectively the value and index of the i-th variable representing j-th component of the SLSI of k-th region. Then,

$$SLSI_{ijk} = \begin{cases} \dfrac{X_{ijk} - \min\limits_{j} X_{ijk}}{\max\limits_{j} X_{ijk} - \min\limits_{j} X_{ijk}} & \text{.... (1a)} \\ & (i = 1,2, ..., I) \\ & (j = 1,2, ..., J) \\ & (k = 1,2, ..., K) \\ \dfrac{\max\limits_{j} X_{ijk} - X_{ijk}}{\max\limits_{j} X_{ijk} - \min\limits_{j} X_{ijk}} & \text{.... (1b)} \end{cases}$$

The numerators in equation (1) measure the extent by which the k-th region did better in the i-th variable representing j-th component of its SLSI as compared to the region (s) showing the worst performance. The denominator is actually the range, *i.e.*, the difference between the maximum and minimum values of a given variable across regions, which is a simple statistical measure of total variation present in that variable. The denominator, in fact, serves as a scale or measuring rod by which the performance of each region is evaluated in a given variable. We note that such a scale can also be identified exogenously utilising scientific standards, social norms and policy targets.

Having calculated the $SLSI_{ijk}$ for all the variables, the indices for the various components of SLSI are calculated as a simple mean of the indices of their respective representative variables. That is,

$$SLSI_{jk} = \frac{\sum_{i=1}^{I} SLSI_{ijk}}{I} \qquad \begin{matrix}(j = 1,2, ..., J)\\(k = 1,2, ..., K)\end{matrix} \qquad .... (2)$$

Then, the composite indicator for each region is calculated as a weighted mean of the component indices obtained from equation (2). That is,

$$SLSI_{k} = \frac{\sum_{j=1}^{J} W_{jk}\, SLSI_{jk}}{J} \qquad (k = 1,2, ..., K) \qquad .... (3)$$

The W_{jk} in equation (3) denotes the weight assigned to the i-th component of the SLSI of k-th region and has the property that: $W_{tk} + .. + W_{jk} = 1$. If the weights are identical and sum to unity, then SLIS is calculated as a simple mean. But when the weights are different across all j and k, SLSI is calculated as a weighted mean. For distinction, the former is denoted simply as SLSI and the latter as SLSI*. Obviously, all the indices and hence, both the SLSI and SLSI*, will be bounded by 0 and 1.

III

EMPIRICAL PROCEDURE AND DATA

To empirically construct SLSI, we follow a simple approach involving the selection of a set of variables having the ability to say something more relevant and substantial about the ecological, economic and equity aspects of SDA. Although more variables can be selected, here, we have selected just three variables each to represent three dimensions of SDA. Ecological security is reflected by the three variables: the proportion of geographical area under forest, per capita utilisable groundwater potential and population density per square kilometre. Since forest occurrence and growth are governed by regional-specific geo-physical conditions, the critical minimum forest cover essential for ensuring ecological security does vary by regions. For instance, the respective critical minimum forest cover norms suggested for the plains, plateau and hills and mountainous regions are 20 per cent, 33.3 per cent and 66.6 per cent respectively (Government of India, 1952). The per capita utilisable groundwater potential indicates the degree of pressure on groundwater resources especially when it is contrasted with the 'water barrier' norm. According to Falkenmark (1984), the water barrier is approached whenever per capita water availability is less than 500 cubic metre. The variable population density was chosen in view of its capacity to reflect the extent of human pressure on the overall environment/resources.

Economic efficiency is represented by the three variables: land productivity in rupees/hectare (Rs./ha), labour productivity in Rs./ha and cereal output per capita. Although expressing productivity in monetary units does help to capture not only physical productivity as influenced by soil fertility, climate, irrigation, technologies, etc., but also the performance of marketing and other rural institutions affecting farm prices, it has, however, the potential to bias the evaluation in favour of regions specialised in high-valued cash crops. It is to counter such a bias, we have included the variable per capita cereal output that also has the potential to say something about the food security status especially when it is contrasted with the critical minimum per capita grain availability, *i.e.*, 180 kilograms/capita/year, suggested by Brown (1991, p. 11).

Social equity is reflected by the three variables: people below the poverty line, female literacy and current groundwater use as percentage of its ultimate potential. While rural poverty captures the effects of employment, income, asset ownership and food consumption, female literacy capturing social equity indicates the potential not only for women's social and economic participation but also for population stabilisation. The intra-generational equity as indicated by poverty and literacy is supplemented by inter-generational equity as indicated by current groundwater use.

Despite their limitations, the selected variables do have a good capacity to reflect the overall ecological, economic and equity aspects of a region's agricultural system. Two observations are due in this regard. First, the variables actually selected to represent a given dimension reflect also the concerns in the other dimensions of agricultural sustainability. For instance, the variables representing the ecological dimension could also indicate indirectly the inter-generational equity potential in view of the direct relationship between ecological security and inter-generational equity. Similarly, groundwater utilisation rate and the two productivity variables reflect also the effects of technology. And, second, most of the variables display both positive and negative correlation among them which, rather than being a problem, actually enhances the capacity of SLSI to capture both the inherent conflicts as also the intrinsic synergy among various aspects of agricultural sustainability.

The data for the nine candidate variables pertaining to the triennium ending 1984-85 for some 80 agro-climatic sub-zones were obtained from Government of India (1991). The sample covered three zones each in Haryana, Kerala and Punjab, four in Karnataka, five each in Bihar, Orissa and Rajasthan, six each in Andhra Pradesh, Maharashtra and West Bengal, seven each in Gujarat and Tamil Nadu, eight in Uttar Pradesh and 12 in Madhya Pradesh. The remaining sub-zones were excluded in view of the absence of comparable data.

Although the SLSI and SLSI* of each sample region were calculated by a straight forward application of equations (1), (2) and (3), a few additional points related to the calculation procedure qualify attention When developing the individual indices, equation (1a) was applied for four variables (*i.e.*, forest cover, land and labour productivities and female literacy) having a positive effect on SDA and equation (1b) was applied for all the remaining variables having an inverse effect on SDA. The identified norms were used as follows. Whenever the value of the variables exceeded their respective norms, then the indices for these variables will be assigned a value of 1. Else, their indices will be based on equation (1).

Even though a number of approaches can be considered for developing weights (see Saleth and Swaminathan, 1992), here, we follow a simple approach. Under this approach, first, the inverse of the proportional contribution of ESI, EEI and SEI to the SLSI was obtained. And then, the weight to be assigned to each component will be the ratio of its inverse contribution to the sum of all the three inverse proportions. Despite its heuristic nature, it has the following appeals: *(i)* since the relative significance of the components of SLSI varies by regions, it assigns differential weights not only across components but also across regions and *(ii)* the weights assigned are also inverse to the relative significance of the three components as reflected by their values. This is due to the fact that as one has more (less) of something (s)he will value it less (more).

IV

AGRICULTURAL SUSTAINABILITY STATUS OF THE AGRO-CLIMATIC SUB-ZONES

The relative agricultural sustainability status of the sample agro-climatic sub-zones as indicated by the values and ranks of their SLSI and SLSI* as well as ESI, EEI and SEI is shown in Table I. The values of ESI, EEI and SEI range respectively from 0.992 to 0.147 from 0.885 to 0.068 and from 0.844 to 0.253. This indicates that the agricultural systems of the sample regions display wider variation in their ecological and economic aspects than in equity aspects. While the SLSI shows a range of 0.645 to 0.214, the SLSI* displays a range of 0.623 to 0.147. Consequently, the SLSI ranking of regions differs significantly from their ranking based on SLSI*. The downward movement of the SLSI* range is due to the effect of the weighting procedure that deflates the better performance slightly but inflates the poor performance substantially. Such an equalising effect is favourable for regions with poor performance as inter-regional priority for investment allocation will be inverse to their ranking. The relatively narrower range of SLSI and SLSI* as compared to their component indices indicates that the performance of regions is not consistent across the three aspects of SDA.

While the mountainous regions in Madhya Pradesh, Karnataka, Kerala and Uttar Pradesh dominated in ecological security, the agriculturally advanced regions in Punjab, Haryana, Uttar Pradesh and Tamil Nadu topped in economic efficiency. The regions that performed better in social equity are mostly in the western coastal regions of Kerala, Tamil Nadu, Karnataka, Maharashtra and Gujarat. Regarding the overall performance of the sample regions in terms of their SLSI*, only about a third of the 80 sample regions located mostly in Madhya Pradesh, Andhra Pradesh, Kerala, Orissa and West Bengal have an SLSI* of above 0.5 and another third of them located mostly in the arid and hilly tracts of Bihar, Rajasthan, Madhya Pradesh, Uttar Pradesh, Gujarat and Tamil Nadu have an SLSI* lower than 0.3. Contrary to expectation, the regions having greater potential for SDA are not in Punjab, Haryana or Western Uttar Pradesh but in Andhra Pradesh, Orissa, West Bengal and Madhya Pradesh as the latter group showed relatively consistent performance across all the components of SLSI as well as the variables representing them.

V

POLICY RELEVANCE OF THE SLSI APPROACH

The policy relevance of the SLSI* approach emerges from the fact that it helps not only to establish inter-regional priority for the allocation of agricultural investment but also to prioritise programmes/projects relevant to each region. While all the regions need attention, under conditions of capital constraints, it is the regions with the poor conditions for SDA, *i.e.*, those with an SLSI* of less than 0.3, that should receive the top priority in agricultural investment. Given the inter-regional investment allocation, the SLSI* approach could also provide further policy guidance as to the specific programmes and projects through which such investment should be channelled to improve the overall agricultural sustainability of each region. Such a regional-specific prioritisation over programmes and projects can be identified by the relative values of the ESI, EEI and SEI. Fo instance, if the ESI of a given region is having a lower value as compared to the other two indices, then, projects focused on afforestation and water conservation should receive higher priority over the economic

TABLE I. THE RELATIVE AGRICULTURAL SUSTAINABILITY STATUS OF THE AGRO-CLIMATIC SUB-ZONES, INDIA, 1984-85

Sr. No.	States/ Agro-climatic sub-zones	Ecological security		Economic efficiency		Social equity		Sustainable livelihood security			
		ESI	Ranks	EEI	Ranks	SEI	Ranks	SLSI	Ranks	SLSI*	Ranks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Andhra Pradesh										
1.	North Coastal Andhra	0.915	6	0.190	57	0.542	23	0.549	15	0.366	43
2.	South Coastal Andhra	0.675	24	0.607	10	0.592	14	0.625	3	0.623	1
3.	Nellore	0.717	14	0.521	18	0.535	27	0.591	8	0.579	3
4.	Rayalaseema	0.663	27	0.189	58	0.413	58	0.422	47	0.326	52
5.	South Telangana	0.351	51	0.129	70	0.470	41	0.317	70	0.235	69
6.	North Telangana	0.954	4	0.465	25	0.464	44	0.628	2	0.560	5
	Bihar										
7.	North Bihar Plains	0.147	79	0.159	66	0.336	73	0.214	80	0.187	78
8.	North-Eastern Plains	0.225	72	0.121	72	0.390	67	0.245	78	0.197	76
9.	South Bihar Plains	0.272	66	0.135	69	0.392	65	0.266	76	0.220	72
10.	Chhota Nagpur Hills	0.382	45	0.105	76	0.442	50	0.310	73	0.208	74
11.	Chhota Nagpur Plateau	0.460	36	0.093	77	0.454	47	0.336	66	0.198	75
	Gujarat										
12.	Southern Hills	0.802	9	0.297	41	0.621	13	0.574	10	0.482	17
13.	South Gujarat	0.690	20	0.301	39	0.649	9	0.547	16	0.475	21
14.	Middle Gujarat	0.334	55	0.195	54	0.590	15	0.373	61	0.306	54
15.	North Gujarat	0.315	59	0.184	60	0.526	29	0.342	64	0.286	59
16.	North-West Arid Area	0.430	38	0.159	65	0.537	25	0.376	60	0.286	57
17.	North Saurashtra	0.353	50	0.224	50	0.578	17	0.385	58	0.332	48
18.	South Saurashtra	0.397	41	0.327	37	0.579	16	0.434	44	0.411	33
	Haryana										
19.	Shivalik Foothills	0.291	65	0.750	4	0.538	24	0.526	24	0.453	23
20.	Plains	0.237	70	0.682	6	0.371	69	0.430	45	0.358	45
21.	Arid Area	0.313	61	0.539	17	0.555	19	0.469	36	0.438	29
	Karnataka										
22.	Northern Dry Region	0.348	52	0.189	59	0.452	48	0.330	68	0.289	56
23.	Central Region	0.292	64	0.167	63	0.451	49	0.303	74	0.258	65
24.	Southern Region	0.373	47	0.639	7	0.486	37	0.500	28	0.476	19
25.	Hills/Coastal Region	0.850	7	0.276	44	0.692	8	0.606	5	0.480	18
	Kerala										
26.	Coastal Midlands	0.200	77	0.191	56	0.830	4	0.407	51	0.262	64
27.	Midlands	0.244	63	0.297	42	0.844	1	0.478	34	0.377	38
28.	Hills	0.688	22	0.338	36	0.832	3	0.620	4	0.535	7
	Madhya Pradesh										
29.	Chhattisgarh Plains	0.699	17	0.441	28	0.467	43	0.536	22	0.514	11
30.	Northern Hills	0.795	10	0.122	71	0.414	57	0.444	43	0.253	67
31.	Bastar Plateau	0.992	1	0.430	31	0.394	64	0.605	6	0.511	12
32.	Bundelkhand	0.677	23	0.447	27	0.436	52	0.520	25	0.500	14
33.	Chhattisgarh Hills	0.691	19	0.112	75	0.397	62	0.400	54	0.233	70
34.	Satpura Hills	0.727	12	0.088	78	0.396	63	0.403	53	0.196	77
35.	Vindhya Plateau	0.706	16	0.437	29	0.489	36	0.544	17	0.522	10
36.	Satpura Plateau	0.742	11	0.456	26	0.428	55	0.542	19	0.510	13
37.	Central Narmada Valley	0.711	15	0.433	30	0.506	33	0.550	14	0.527	8
38.	Gird Region	0.722	13	0.474	23	0.501	34	0.565	12	0.546	6
39.	Jhabua Hills	0.406	40	0.085	79	0.441	51	0.311	72	0.181	79
40.	Mawa/Nimar Plateau	0.370	48	0.426	32	0.357	70	0.384	59	0.382	37

(Contd.)

TABLE I (*Concld.*)

Sr. No.	States/ Agro-climatic sub-zones	Ecological security		Economic efficiency		Social equity		Sustainable livelihood security			
		ESI	Ranks	EEI	Ranks	SEI	Ranks	SLSI	Ranks	SLSI*	Ranks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Maharashtra										
41.	Eastem Vidarbha	0.608	32	0.408	34	0.519	30	0.512	27	0.498	15
42.	Westem Hills/Plains	0.384	43	0.247	47	0.716	7	0.449	41	0.373	41
43.	Scarcity Region	0.692	18	0.213	51	0.546	22	0.484	30	0.377	39
44.	Central Plateau	0.377	46	0.118	74	0.473	39	0.323	69	0.226	71
45.	Central Vidarbha	0.688	21	0.119	73	0.535	26	0.447	42	0.256	66
46.	Konkan	0.270	68	0.160	64	0.801	5	0.410	50	0.268	63
	Orissa										
47.	Inland	0.958	3	0.506	20	0.472	40	0.645	1	0.584	2
48.	Northem Plateau	0.959	2	0.137	68	0.461	45	0.519	26	0.286	58
49.	South-Westem Hills	0.929	5	0.466	24	0.399	61	0.598	7	0.524	9
50.	Coastal Region	0.648	29	0.202	53	0.640	10	0.497	29	0.373	42
51.	Ganjam	0.647	30	0.247	48	0.547	21	0.480	32	0.404	34
	Punjab										
52.	Northem Punjab	0.313	60	0.741	5	0.568	18	0.541	21	0.476	20
53.	Central Punjab	0.228	71	0.885	1	0.629	12	0.581	9	0.422	31
54.	Southem Punjab	0.303	62	0.825	3	0.458	46	0.529	23	0.448	24
	Rajasthan										
55.	Northem Arid Region	0.317	58	0.594	11	0.373	68	0.428	46	0.399	35
56.	Southem Plains	0.392	42	0.546	14	0.273	79	0.404	52	0.373	40
57.	Eastem Plains	0.369	49	0.634	9	0.392	66	0.465	37	0.439	27
58.	Southem Plateau	0.433	37	0.411	33	0.337	72	0.393	57	0.389	36
59.	Westem Arid Region	0.343	53	0.068	80	0.353	71	0.254	77	0.147	80
	Tamil Nadu										
60.	Northem Region	0.383	44	0.246	49	0.253	80	0.294	75	0.282	61
61.	Central Region	0.337	54	0.267	45	0.424	56	0.343	63	0.331	49
62.	North-Eastem Coast	0.270	67	0.299	40	0.428	54	0.332	67	0.320	53
63.	Delta	0.209	76	0.639	8	0.500	35	0.449	40	0.359	44
64.	South-Eastem Coast	0.330	57	0.170	62	0.516	32	0.339	65	0.277	62
65.	Southem Region	0.237	69	0.583	12	0.838	2	0.552	13	0.421	32
66.	Hills Region	0.554	34	0.309	38	0.761	6	0.541	20	0.472	22
	Uttar Pradesh										
67.	Westem Hills	0.669	26	0.291	43	0.476	38	0.478	33	0.426	30
68.	North-Eastem Plains	0.544	35	0.512	19	0.332	74	0.463	38	0.441	26
69.	Eastem Plains	0.167	78	0.204	52	0.289	78	0.220	79	0.209	73
70.	Vindhya Hills	0.819	8	0.400	35	0.408	59	0.543	18	.0.486	16
71.	Central Plains	0.557	33	0.543	15	0.322	75	0.474	35	0.445	25
72.	North-Westem Plains	0.213	74	0.875	2	0.298	77	0.462	39	0.327	51
73.	South-Westem Plains	0.224	73	0.559	13	0.402	60	0.395	55	0.343	46
74.	Bundelkhand	0.651	28	0.485	22	0.308	76	0.481	31	0.438	28
	West Bengal										
75.	Barind Region	0.212	75	0.504	21	0.468	42	0.395	56	0.340	47
76.	Alluvial Region	0.147	80	0.259	46	0.528	28	0.311	71	0.239	68
77.	Coastal Region	0.333	56	0.178	61	0.517	31	0.343	62	0.284	60
78.	Rarh & Eastem Plains	0.609	31	0.540	16	0.549	20	0.566	11	0.565	4
79.	Terai Region	0.669	25	0.157	67	0.433	53	0.420	48	0.295	55
80.	Hills Region	0.417	39	0.195	55	0.638	11	0.417	49	0.330	50

and social oriented programmes.

In terms of the results presented in Table I, the ten regions requiring the most immediate policy attention are the western arid region of Rajasthan, Jhabua hills and Keymore plateau regions of Madhya Pradesh, all the five sub-zones of Bihar, the central plateau of Maharashtra and finally, the eastern plains of Uttar Pradesh. While in the case of the two Madhya Pradesh regions, the programmes for SDA should focus more on economic and equity aspects, in the case of the remaining eight regions, the programmes should focus more on ecological and economic aspects.

VI

CONCLUDING COMMENTS

The major limitation of the SLSI approach is its assumption of the agricultural system of a given region as a closed system independent of that of other regions. The weighting scheme, though intuitive, is heuristic rather than scientific. While the cross-sectional basis of the SLSI approach enables it to be generalised for ranking various households, projects and programmes and even nations in a global context, it is not of much help for evaluating sustainability in an inter-temporal context. Thus SLSI functions only as a mere litmus test or screening device for ranking different entities but fails to provide any accurate quantitative information on agricultural sustainability. Despite these and other drawbacks of the SLSI approach, its simplicity, information-efficiency and generalisability make it a readily available and easily understandable tool for evaluating the relative potential for agricultural sustainability within the currently binding information constraint.

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