RESEARCH ARTICLE

An index to measure sustainability of sugarcane based dairy farming

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Abstract: An index to measure the sustainability of sugarcane based dairy farming was developed by adopting a systematic procedure. The scale values of the three dimensions economic, social and environment were calculated which were found to be 7.42, 6.76 and 6.82, respectively. Out of 83 indicators under selected dimensions, 74 were retained for item analysis. Based on the rating of 33 judges on a three point relevancy continuum, mean relevancy and overall mean relevancy scores were calculated. The statements having relevancy weightage (RW) > 0.85 and Mean Relevancy Score (MRS) greater than the Overall Mean Relevancy Score i.e., 2.60 were considered for inclusion in Sugarcane Based Dairy Farming Sustainability Index (SBDFSI). The final index contains 44 indicators.

Key words: Dairy farming, index, sustainability, sugarcane

Introduction

Dairy farming can effectively be used to arrest negative effects of present day challenges to crop farming as well as to improve and maintain sustainability of farming for a longer period of time with livelihood security to the rural masses. Livestock is an integral part of India's agricultural economy and plays a multifaceted role in providing livelihood support to the rural population. Apart from contributing to national economy in general and to agricultural economy in particular, also provides employment generation opportunities, asset creation, coping mechanism against crop failure and social and financial security. Livestock is the main source of animal protein for the population (Anonymous, 2013). To meet the growing demand of feed and fodder necessitates the exploration of the alternative sources for meeting the feed and fodder requirement for sustainable dairy farming. In this direction among the various crops based dairy farmings, sugarcane crop based dairy farming offer an excellent opportunity as sugarcane crop contributes a lot to the dairy farming in the form of fodder, fuel, litter and housing material, and sugarcane represents an example whose by-products can be maximally utilized (Kung and Stanley, 1982; Kevelenge *et al.*, 1983; Nasseven, 1986 and Wanapat, 1990). In sugarcane growing areas still there is a scope to improve the status of dairy farming as the elasticity coefficient in general and livestock and sugarcane based farming system were found significant (Singh, *et al*., 2010). However, careless intensification of dairy farming to be avoided as it is accelerating the climatic change which is clearly pointed out by Marek, 2012 that in addition to its economic and social dimension, the dung and dairy industry is responsible for a significant amount of national greenhouse gas (GHG) emissions contributing to climate change. Notably, in the rainy season when cow dung is not dried but dumped or washed into the rivers, emissions from anaerobic digestion are released. Conservative estimates of the total emission reduction potential from the non-utilized dung of the livestock industry are 4.3 million Co_2 per year. Therefore, any attempt to increase the production and productivity of dairy animals will not be successful until and unless it is practiced in sustainable manner even in most potential geographical locations e. g. sugarcane dominated areas. Thus, studies on sugarcane based dairy farming with sustainability angle are the need of the hour. To conduct these type of study, measurement of sustainability is tedious process for which limited number of measuring tools are available and literature search revealed that none of the measuring tool is available to measure the sustainability of sugarcane based dairy farming hence an attempt has been made to develop an index to measure it.

Materials and Methods

This section on research methodology has usually deals with procedural steps required to accomplish the objectives laid down for the investigation. In this section, an attempt has been made to explain the various methods and procedures followed to devise the Sugarcane Based Dairy Farming Sustainability Index.

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Formulation of construct

It is imperative to operationalise the different concept for ease of measurement. In other words construct to be formulated in light of the scientific study. A construct is a concept. It has the added meaning, however, of having been deliberately and consciously invented or adopted for a special scientific purpose (Kerlinger, 2012). Different constructs devised/adopted for present purpose are as under:

Sugarcane based dairy farming**:** Sugarcane based dairy farming is one where major share in total accrued agricultural income is from sugarcane crop and related activities along with substantial share from dairy farming, and the rest from other enterprises operated by the farmers irrespective of whether they are having their own land or not.

Sustainability: Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundland, 1987). It is a characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generation or population in other locations to meet their needs (MEA, 2005).

Sustainability of sugarcane based dairy farming: Sustainability of sugarcane based dairy farming is operationalised as the degree to which dairy farming is practiced in the manner which is economically efficient, socially supportive to the society, environmentally sound in long term perspective under sugarcane dominated farming system. It is taken as a composite of three indices, i.e. economic sustainability index (ESI), social sustainability index (SSI), environmental sustainability index (EnSI) so that it took the stock of both, the conflict and synergy between ecological, social and environmental aspects. To measure it, sugarcane based dairy farming sustainability index (SBDFSI) was constructed as follows:

Development of Sugarcane Based Dairy Farming Sustainability Index (SBDFSI)

Sustainability index requires selection of various dimensions of sustainability and indicators for assessing the sustainability of sugarcane based dairy farming. Composite indicators that integrate various measures into an index can be useful tools for measuring sustainability.

Selection of the dimensions of the index

To develop the index, three dimensions economic, social and environmental were included.

Economic Sustainability*:* It is operationally defined as the endurance and efficiency of dairy farm enterprise which is enunciated through productive and reproductive parameters of dairy animals, net profit, input-output ratio, farmers margin as well as marketing efficiency of dairy farming under sugarcane dominated farming system.

Social Sustainability*:* It refers to the level of social well being of farmers and their families practicing sugar cane based dairy farming in terms of community relation, social responsibility/ ethics and infrastructural facilities along with support services utilization as well as access patterns.

Environmental Sustainability*:* It is operationalized as the practicing of sugarcane based dairy farming taking into consideration the proper animal welfare, animal waste management, natural area conservation, preparedness for unforeseen situations like drought, flood, disease epidemic, without compromising ecological parameters in long term perspective.

Determination of scale values of dimensions: It has been decided to give specific weights (Scale Values) to each dimension of the SBDFSI based on their perceived significance. The Normalized Rank Order Method suggested by Guilford (1954) was used for determining the scale values. This method could be used with any number of variables and does not require a large number of judges.

Judges' rating**:** As per the Normalized Rank Order Method, three different dimensions of SBDFSI were ranked by the judges according to their perceived significance in determining the status of sustainability of dairy farming. Judges are the experts in the field of Social Science, Extension Education and Rural Developments. Questionnaires containing dimensions of SBDFSI were sent by post, through e-mail and also handed over personally to 250 judges for ranking. Judges were requested to assign rank varying from 1-3 to the dimensions according to their relevance. Only 38 judges returned the filled in questionnaires. Out of 38 responses, 5 responses were found unsuitable for analysis and eliminated after careful examination of responses. The remaining 33 responses were considered for analysis. The rankings given by all 33 judges were summarized and presented in table 1.

Calculation of proportions*:* The proportions were worked out for the ranks assigned by all the judges. The formula is $p = \frac{(Ri - 0.5)100}{n}$, where R_i stands for the rank value of the dimension "i" in the reverse order as 3 to 1 and "n" indicates the number of dimensions ranked by the judges. The *p* is the centile value which indicated the area of the dimensions in the normal distribution. The *p* values were worked out for all the ranks shown in Table-1. Thus, *p* values for the ranks ranged from lowest 16.67 to 83.33.

Determining the C Values*:* The correct rank order (1 to 3) is given in the column order R_i in Table-1. The second column R_i in Table-1 is the reverse rank order (3 to 1). The C values were

Table-1: Frequencies of ranks, proportions (*p*), C values and R_c values for three dimensions of SBDFSI

r_i	R_i	Dimensions			Σ	p	C
		Economic Sustainability	Social Sustainability	Environmental Sustainability			
1	3	20	4	9	33	83.33	8
2	2	7	17	9	33	50.00	7
3	1	6	12	15	33	16.67	6
Σf_{ji}		33	33	33	99	150.00	21
$\Sigma (f_{ji}C)$		245	223	225	693		
Mc or Rj or Rc (Σ fjiC/ Σ fji)		7.42	6.76	6.82	21	Mean C = 7 Mean total fji = 7 SD = 0.37	

r_i = Correct Rank Order, R_i = Reverse Rank Order, Σ = Sum, *p* = Proportion, C = C values of respective ranks, M_c = Mean Value, R_j = Response value, R_c = Scale Value, σ = Standard Deviation

Standard Error for $M_C = \frac{\sigma}{\sqrt{N}} = \frac{0.37}{\sqrt{33}} = 0.06$

determined for each rank from the Table-M (Guilford, 1954). These values can be traced by putting the finger on the column extreme left of the Table-M, on the number which indicates the number of stimuli used in the experiment. In the case of this experiment the numbers of dimensions were 3 thus, the number of stimuli to be ranked were 3. While moving the finger from this number 3 towards right, stop at the number which indicates the rank (r_i, 3). Above the rank number you can find the respective C value 6 for the rank 3 and this can be entered in the Table 1 under the letter C. The C values are from 1 to 9 only. The same procedure may be adapted in finding out the C values for all the ranks (r_i) from the Table-M.

Calculation of $\Sigma(f_{ji}C)$ value for all the dimensions*:* This value for every dimension was obtained by multiplying the frequencies found in the columns of the respective dimension by the C values of the rank (r_i), and summing up the products for each dimension and entering the same in the row against $\Sigma (f_{ji}C)$. The mean of the total frequencies, that is for the whole data of the matrix was 7.00 ($\frac{693}{99} = 7.00$) and the mean of the C values was 7.00 ($\frac{21}{3} = 7.00$).

Calculation of scale values of dimensions*:* Then the $\Sigma (f_{ji}C)$ values for each dimension was divided by the total number of judges 33, which resulted in obtaining the $M_c = R_j$. The treatment of data can be stopped at this stage and the M_c values can be accepted and treated as the scale values. The scale values for economic, social and environmental sustainability were 7.42, 6.76 and 6.82, respectively. The sum of these values was 21, which was also the total sum of the C values, indicating the accuracy of calculation. As per the procedure, sum of the scale values and C values should be same. The mean of the M_c or R_j or R_c values was 7.00. The standard deviation and standard error of the M_c values were 0.37 and 0.06, respectively (Table 1).

Selection of the indicators of sustainability: Selection of effective indicators is the key to the overall success of any measuring instruments. To measure the sustainability, indicators under each dimension were selected after preliminary survey of the study area, consultation of the literature as well as the experts such as scientists, officials of the related departments and personnel from NGOs working in the area. Due care was taken to include all relevant items. The procedure involved could ensure the efficiency of the instrument to measure the sustainability of sugarcane based dairy farming by ascertaining content validity. Keeping in view the context of study, following proposed indicators under economic, social and environmental were tested and the following steps were followed for selecting relevant indicators under each dimension of SBDFSI:

Collection and editing of indicators*:* By referring the available literature on relevant subject, consultation of the researchers, farmers and extension experts, a total of 83 items (indicators) were collected covering the almost entire universe or content. The indicators were edited as per the 14 informal criteria suggested by *Edwards* (1957) and as an outcome 9 indicators were eliminated. Finally, 74 indicators were retained after editing and considered for judges' rating.

Judges' Rating*:* Selected indicators were subjected to the judges rating on 3 point continuum i.e. most relevant, relevant and not relevant with respective scores of 3, 2 and 1. The questionnaire containing 74 indicators on a three point continuums were sent by post, through e-mail and also handed over personally to a 250 judges. These judges were experts in the field of extension education, social science and rural development, etc. Out of 250 judges 38 judges had returned the same set of indicators after duly recording their judgments in a stipulated span of two month.

Table-2: A list of selected indicators with MRW, Mean Relevancy Score (MRS) for construction of sustainability index

Sl. No.	Indicators	RW	MRS
	A) Economic Sustainability		
I.	Productive and reproductive performance of dairy animals		
1.	Lactation length	0.92	2.76
2.	Dry period	0.88	2.64
3.	Conception rate	0.89	2.67
4.	Lactation milk yield	0.91	2.73
5.	Age at first calving	0.88	2.64
II	Economic efficiency		
a)	Production efficiency		
1.	Net profit (Gross income-gross expenditure)	0.90	2.70
2.	Input-output ratio	0.91	2.73
3.	Farmers margin	0.89	2.67
b)	Marketing efficiency		
1.	Milk disposal channels	0.89	2.67
2.	Distance of milk marketing place	0.88	2.64
3.	Time (channel wise and agent wise)	0.89	2.67
4.	Price of milk paid by the consumers	0.89	2.67
5.	Price of milk received by the producers	0.95	2.85
	B) Social Sustainability		
I.	Community relation of the farmers		
1.	Involvement in any community activities	0.91	2.73
2.	Membership/office bearers of organizations related to dairy farming	0.92	2.76
II	Infrastructural facilities & support services utilization as well as access patterns		
1.	Connectivity of village to the road	0.93	2.79
2.	Existence of infrastructural facilities	0.97	2.91
3.	Access and utilization of the different infrastructural facilities and services provided by different institutions	0.89	2.67
4.	Access of farmers to the dairy farming technologies	0.89	2.67
5.	Utilization of dairy farming technologies by the farmers	0.94	2.82
III.	Social responsibility/Ethics		
1.	Clean milk production	0.93	2.79
2.	Observance of best health care practices by the farmers	0.89	2.67
3.	Proper transportation of animals	0.93	2.79
	C) Environmental Sustainability		
I.	Animal welfare		
1.	Provision of adequate space as per the age, conditions & species of animals	0.90	2.70
2.	Housing condition in the cattle shed	0.91	2.73
3.	Overall health of animals	0.87	2.61
4.	Balance ration to the animals	0.94	2.82
5.	Provision of adequate clean potable water for animals	0.93	2.79
II.	Animal waste management		
1.	Dung and leftover storage mechanism	0.88	2.64
2.	Utilization of waste materials like dung, leftover, urine, etc (Establishment of bio-gas plant), disposal of dead animals, placenta & other waste like horn, hair, packets of insecticides, etc.	0.88	2.64
III.	Natural area conservation		
1.	Sustained pastures management	0.94	2.82
2.	Sustainable ecological management of cultivated areas focused to promote bio-diversity	0.93	2.79
3.	Utilization of crop by-products for animal feeding to achieve better nutrient recycling	0.93	2.79
IV.	Preparedness for unforeseen situations like drought, flood, disease epidemic, etc.		
a)	Individual farmer level (micro level)		
1.	Preservation of fodder (Silage and hay)	0.91	2.73
2.	Sufficient storage of straw and crop residues	0.88	2.64
3.	Proper de-worming and vaccination of animals in advance at proper time	0.92	2.76
4.	Use of sugarcane leaves, extra tillers, tops, bagasse, etc as fodder during drought and flood situations	0.90	2.70
b)	Community level (meso Level)		
1.	Proper maintenance of community grazing areas like road side, canal bank, river bank *etc*.	0.89	2.67
2.	Development and creation of water resources as well as maintenance of existing ones	0.88	2.64
3.	Establishment of fodder bank at community level	0.94	2.82
A.	At government level (Macro)		
1.	Awareness campaign/advisory to make aware the farmers about various measures to deal with the unforeseen situations	0.94	2.82
2.	Inputs supply at subsidized rate during the natural calamities	0.87	2.61
3.	Soft and easy loan to the farmers	0.88	2.64
4.	Campaign for de-worming and vaccination of animals to prevent disease outbreaks	0.90	2.70

Out of 38 responses, 5 responses were found unsuitable for item analysis and eliminated after careful examination of responses. The remaining 33 responses were considered for the item analysis.

Relevancy Test*:* These indicators were subjected to scrutiny and their subsequent screening for inclusion in the final index. The judges were asked to indicate degree of relevancy on each indicator in three point continuums 'Most Relevant, Relevant and Not Relevant' with respective scores of 3, 2 and 1. The relevancy weightage (RW) and mean relevancy score (MRS) were worked out for all the selected indicators individually as well as overall mean relevancy score (OMRS) including all the indicators was calculated by using the following formula:

$$RW = \frac{(\text{Most relevant response}*3+\text{Relevant response}*2+\text{Not Relevant response}*1)}{\text{Maximum possible score}}$$

$$MRS = \frac{(\text{Most relevant response}*3+\text{Relevant response}*2+\text{Not Relevant response}*1)}{\text{Number of Judges}}$$

$$OMRS = \frac{(\text{Most relevant response}*3+\text{Relevant response}*2+\text{Not Relevant response}*1)}{\text{Number of Judges x Number of statements}}$$

By these two criteria the statements having relevancy weightage (RW) > 0.85 and Mean Relevancy Score (MRS) greater than the Overall Mean Relevancy Score i.e., 2.60 were considered for inclusion in Sugarcane Based Dairy Farming Sustainability Index (SBDFSI) and finally 44 indicators were included. The finally selected dimensions of Sugarcane Based Dairy Farming Sustainability Index and statements under these with respective relevancy weightage as well as mean relevancy scores are given in Table-2.

Construction of the composite sugarcane based dairy farming sustainability index

The first step is to construct the index (Iij) for each i^{th} indicator representing j^{th} dimension of composite sustainability index. For making indicator scale free following methods was applied:

$$I_{ij} = \frac{Xij - MinXij}{Max\ Xij - MinXij} \quad (1)$$

$$I_{ij} = \frac{MaxXij - Xij}{Max\ Xij - MinXij} \quad (2)$$

Where

i = 1, 2, 3……..n Indicators

j = 1, 2, 3 Dimension of Sustainability

$\mathbf{X_{ij}}$ = Value of i^{th} indicator of j^{th} dimension

Equation (1) will be applied for indicators having positive implication on sustainability.

Equation (2) will be applied for indicators having negative implication on sustainability.

Having calculated the I_{ij} for all the indicators, the second step is to calculate the indices for various dimensions of composite sustainability index. It is calculated as the simple mean of their respective variables, that is:

$$ESI = \frac{\sum_{i=1}^{n} Iij}{n}, \quad SSI = \frac{\sum_{i=1}^{n} Iij}{n} \text{ and } EnSI = \frac{\sum_{i=1}^{n} Iij}{n}$$

Whereas,

ESI= Economical Sustainability Index

SSI=Social Sustainability Index

EnSI=Environmental Sustainability Index

Iij= Index for the jth dimension containing n indicator

n= No. of indicators

Then, the composite Sugarcane Based Dairy Farming Sustainability Index for each respondent will be calculated as a weighted mean of the indices obtained for different dimensions of the sustainability in following manner:

$$SBDFSI = \frac{W1*ESI + W2*SSI + W3*EnSI}{\text{Sum of the scale values of all dimensions}}$$

Whereas,

W = Scale value (weight) assigned to the respective dimension of composite sustainability index.

(Chand and Sirohi, 2013)

Standardization of Index

The validity of the instrument was assessed by content validity. The content of the index was thoroughly covered with literature scan and expert opinions. The indicators having relevancy score of >0.85 were retained. As it indicates that more than 85 per cent of judges rated the statement as relevant which indicates that statement is unambiguous. This indicated validity of the index content. As the scale values, relevancy weightages and mean relevancy scores of all the dimensions and indicators had

Table-3: Distribution of respondents according to sugarcane based dairy farming

Sl. No.	Variables	Category	Frequency	Percentage
1.	Economic Sustainability	Low (<0.22)	6	15.00
	(Mean=0.48)	Medium (0.22-0.74)	25	62.50
		High (>0.74)	9	22.50
2.	Social Sustainability	Low (<0.15)	7	17.50
	(Mean=0.40)	Medium (0.15-0.64)	26	65.00
		High (>0.64)	7	17.50
3.	Environmental Sustainability	Low (<0.28)	7	17.50
	(Mean=0.49)	Medium (0.28-0.71)	28	70.00
		High (>0.71)	5	12.50
4.	Overall Sustainability	Low (<0.26)	5	12.50
	(Mean=0.46)	Medium (0.28-0.71)	30	75.00
		High (>0.66)	5	12.50

Table 4. Relationship between profile variables and composite sustainability of sugarcane based dairy farming

Sl. No.	Profile characteristics of the farmers	Correlation coefficient (r value)
1.	Age	0.0549 ^{NS}
2.	Education of the family head	0.5695**
3.	Family educational status	0.4861**
4.	Family size	0.2457 ^{NS}
5.	Social participation	0.6261**
6.	Decision making pattern	-0.0872 ^{NS}
7.	Occupation	-0.2319^{NS}
8.	Operational land holding	0.6325**
9.	Income	0.6509**
10.	Herd size	0.0615 ^{NS}
11	Mass media exposure	0.5671**
12.	Extension contact	0.5634**

**<p=0.01

discriminating values, it seemed reasonable to accept the index as valid measure of the desired dimension.

Final Sugarcane based dairy farming sustainability index and administration of it

The final index consisting of 44 (Table-2) indicators arranged under three dimensions of the sustainability can be administered to respondents to measure the sustainability of the sugarcane based dairy farming. Since the index is scale free, the overall possible maximum and minimum score of sustainability ranges between 1 to 0. The score approaching unity will indicate high level of sustainability and *vice-versa*.

Results and Discussion

The final set of the 44 statements which represent the sustainability of sugarcane based dairy farming, was administered on form of interview schedule to a fresh group of 40 farmers, which were not included in the actual sample. It was observed that the average indices for economic, social, environmental and overall sustainability of sugarcane based dairy farming were found to be 0.48, 0.40, 0.49 and 0.46, respectively. It was observed that majority (62.50%) was farmers were having medium (0.22-0.74) economic sustainability followed by 22.50 and 15.00 per cent of them had high (>0.74) and low (<0.22) levels of economic sustainability. In case of social sustainability it was observed that majority (65.00) of the farmers appeared in the medium (0.15-0.64) category of social sustainability while, an equal proportion (17.50%) of them fell in the high and low levels of it. With respect to the environmental sustainability it was observed that majority (70.00%) of the farmers had medium (0.28-0.71) sustainability, however, 17.50 and 12.50 per cent of the farmers were having low (<0.28) and high (>0.71) levels of environment sustainability, respectively. Further, as for as overall sustainability of sugarcane based dairy farming was concerned it was found that majority (75.00%) of the farmers had medium (0.28-0.71) sustainability followed by an equal (12.50%) of them were having high (>0.66)

and low (<0.26) sustainability (Table-3). It could be conclude that dimensions wise as well as overall sustainability wise majority of the farmers had medium sustainability of sugarcane based dairy farming. This might be due to the fact that majority of the farmers were found to possess small to medium herd size with comparatively more numbers of either low producing or unproductive animals in the herd resulted low scale of economy, small land holding size in majority of the cases compelled them to purchase feed and fodder which increased the cost of production, low price of milk and high cost of inputs resulted in less net income, inadequate awareness about the management of animal wastes decreased environmental sustainability, inadequate infrastructural facilities and support services led to the disease incidences, forced sell, increase in the cost of production, further, low level of preparedness to combat the natural calamities at community as well as at government level resulted in lower sustainability. Though, the sustainability of sugarcane based dairy farming was medium but for making it as an viable employment alternative to landless, marginal and small farmers to provide them livelihood security in face of the further land fragmentation as well as decreasing productivity of crops, it must be highly sustainable. To make it highly sustainable, farmers must be educated to use viable innovative technologies, rear highly efficient animals like indigenous milch breeds of cow, murrah buffalo and cross bred cow, to profess it as an commercial venture, diversification to increase the profitability and to follow highly efficient way of waste disposal mechanism. The farmers alone may not be able to achieve the target of high sustainability thus, support at community level is warranted in the form of effective management of water bodies, grazing lands, pastures and efforts to establish marketing facilities. Creation and delivery of some of the facilities and services are beyond the capacity of individual farmers as well as the community here government has to take the lead. The infrastructural facilities like dairy cooperatives, veterinary hospitals, AI centers, establishment of small milk processing plants, disease surveillance & management, vaccination and effective law enforcement management may be taken care by the government. To make the sugarcane based dairy farming highly sustainable, all stakeholders namely farmers, local *Panchayats*, sugar mills, field level officials and other line departments of state government should work together effectually.

Relationship between profile variables and composite sustainability of sugarcane based dairy farming:

Results given in Table 4 revealed that education of the family head, family educational status, social participation, operational land holding, income, mass media exposure and extension contact were highly significantly related with composite sustainability of sugarcane based dairy farming. Further, it was noted that age, family size, decision making pattern, occupation and herd size did not show any relation with composite sustainability of sugarcane based dairy farming. It could be conclude that most of the profile characteristics were found to be positively related with composite sustainability of sugarcane based dairy farming. It implies that to improve the sustainability, these traits like education, social participation, income, mass media exposure and extension contact be managed properly. In case of age it may be said that mature people concerned more about the society and surrounding, have good ideas being experienced person and behave more responsibly thereby, age depicted positive relation with sustainability.

Conclusions

Validity of the index indicates the precision and consistency of the results. Information on sustainability aspect of sugarcane based dairy farming would be a priceless resource to policy makers for designing policies in order to reduce vulnerabilities of the sector as well as farmers. This index can be used to measure the sustainability of dairy farming beyond the study area with suitable modifications and evaluation of reliability and validity.

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