Development of analytical hierarchy process based dairy index for assessment of the dairy sector in different states of India

In India, the major indicators used to assess the dairy sector are the age-old criteria of considering only the total production and per capita availability. Such indicators may not be able to adequately assess the development of the dairy sector. First, the indicators inadequately capture the complete scenario of the dairy sector. Secondly, dairy as a sector has multistakeholder dependency. Different stakeholders want to direct the sector in their perspective which pertains to social, economic or environmental domains. Thirdly, India is a resource-constraint nation, which makes it important for it to judiciously allocate its resources to achieve maximum benefits for which such indicators provide incomplete scenario.

The quantity and composition of milk is influenced naturally by two kinds of factors, some related to the secretion from the mammary gland (lactation state, health status, animal species) and others to external factors such as season, nutritional status of the cow and environment[1,2]. Additionally, the environmental factors (e.g. soil type, location of the farm, etc.) influence the quality of milk[3–8] and there is correlation of these elements present in milk and cows' feed with the milk quality[9–11]. Using a multiple component identification method, factors affecting the quality of milk can be identified at one or more critical points in the dairy production chain. The quality of milk received by the consumer is the composite resultant of all the factors prior to milking of the animal to the post-milking processing, transport and handling of the milk at the receiver's end. We utilize the Analytical Hierarchy Process (AHP) for determining the performance of dairy sector and to track the progress of the same over a period of time.

The fundamental AHP methodology is based on riving a complex problem into several hierarchical levels and deriving ratio scales from paired comparisons of criteria for each level. It has three steps as problem modelling, weights valuation, weights scoring and ranking.

In problem modelling, the states are selected as the different alternatives need

Table 1. Criterion characteristics selected for AHP

General criteria Level 1	Specific criteria Level 2	Sub-specific criteria Level 3	Indicator	Cost/benefit	Description
Livestock resource	Quality	Cross bred	No. of milch animals	Benefit	It is characteristic that forms the very basis for inception, development and progress of dairy sector
		Indigenous	No. of milch animals	Benefit	
		Buffalo	No. of milch animals	Benefit	
	Quantity	Wet average	Total production/ animals in milk	Benefit	It is characteristic for productivity of livestock resources
		Production gap	Wet average – per animal production	Cost	It is characteristic for unproductivity of livestock resources
Infrastructure	Service sector	Vet hospitals	Numbers	Benefit	These are indicative of the services provided for development and working of an efficient dairy system
		Semen stations	Numbers	Benefit	
		Dairy plants	Numbers	Benefit	
	R&D/Man power generation	–	Numbers of research institutes	Benefit	
Output	Quantity	Total milk production	Total milk production	Benefit	It is characteristic of production
		Per capita milk availability	Total production/total population	Benefit	It is characteristic of production per capita
	Quality	–	% of failed samples	Cost	It is characteristic of quality of milk

Table 2. Relative scores for AHP and explanation

Intensity of importance	Definition (verbal scale)	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Very strong importance	An activity is favoured very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	

Source: Saaty[20].

Table 3. Pair-wise final criteria weightages

Level 1	Weight	Level 2	Weight	Level 3	Weight	Global weight
Livestock resources	0.49	Quality	0.5	Cross bred	0.08	0.0196
				Indigenous	0.46	0.1127
				Buffalo	0.46	0.1127
		Quantity	0.5	Wet average	0.5	0.1225
				Production gap	0.5	0.1225
Infrastructure	0.06	Service sector	0.88	Veterinary hospitals	0.71	0.037488
				Semen stations	0.06	0.003168
				Dairy plants	0.23	0.012144
		R&D/Manpower	0.12	–		0.0072
Output	0.45	Quantity	0.5	Total milk production	0.5	0.1125
				Per capita availability	0.5	0.1125
		Quality	0.5	–		0.225

Table 4. Ranking of states according to different parameters

States	TMP rank	PCMA rank	Ranking without quality	Overall rank	Difference*
A&N Islands	31	19	27	12	15
Andhra Pradesh	3	7	3	2	1
Arunachal Pradesh	30	31	29	25	4
Assam	20	30	18	17	1
Bihar	10	15	8	16	–8
Chandigarh	28	23	21	18	3
Chhattisgarh	18	20	15	24	–9
D&N Haveli	33	24	34	22	12
Daman & Diu	34	34	33	34	–1
Delhi	21	32	24	23	1
Goa	26	26	28	13	15
Gujarat	4	5	6	11	–5
Haryana	8	2	9	9	0
Himachal Pradesh	19	6	14	15	–1
J&K	16	10	17	20	–3
Jharkhand	15	17	19	28	–9
Karnataka	11	12	11	6	5
Kerala	13	13	20	14	6
Madhya Pradesh	6	9	4	5	–1
Maharashtra	7	14	7	7	0
Manipur	24	29	31	32	–1
Meghalaya	23	28	26	31	–5
Mizoram	32	33	32	33	–1
Nagaland	25	25	30	29	1
Orissa	14	21	13	21	–8
Pondicherry	27	22	23	10	13
Punjab	5	1	5	8	–3
Rajasthan	2	3	2	4	–2
Sikkim	29	16	22	27	–5
Tamil Nadu	9	4	10	3	7
Tripura	22	27	25	30	–5
Uttar Pradesh	1	11	1	1	0
Uttarakhand	17	8	16	26	–10
West Bengal	12	18	12	19	–7

*Difference = (rank without quality parameters – rank with quality parameters).
Positive values show improvement in rank of states if quality parameters are considered.
Negative value shows fall in ranks of states after the quality parameters are considered.

to be compared using common criteria to predict the performance index and ranking. The dairy system is divided into three main criterion characteristics: livestock resources (LR), infrastructure (I) and output (O). Each of these characteristics has further sub-criteria up to level 2 and level 3 (Table 1). The indicators used for each of the criteria are shown in Table 1 along with the description and their cost/benefit selection.

In weights valuation, a pair-wise comparison amongst the criteria is made by giving the relative weightage on the numerical scale of 1 to 9 to obtain the global/local weightages of the criteria[12] (Table 2). In the present case, criterion characteristics and criteria weightages were determined with elaborative field study and interview of the experts including government officials, dairy development officers and food safety officers. To maintain the uniformity, data of 2012 is used for all the different criteria and alternatives[13,14]. Table 3 provides a snapshot of the number of indicators in each domain and sub-domain along with weights.

In weights scoring and ranking, an overall ranking of the alternatives based on the total weighted score of the alternatives for the given criteria is created. The ranking was obtained by the summation of the product of the criteria and alternative's weightages as shown below

$$R = \sum 11\ P_{(i,j)} w_{(i)}\ (1)\ i\ i = 1,$$

where R_j is the ranking of the alternatives, P_{ij} the normalized criteria score of the alternatives and w_i is the criteria weight.

A multi-criteria decision making tool (using AHP) of ranking the best states in terms of dairy was developed keeping the perspective of both quantity and quality. The new Dairy Index consists of 12 indicators grouped in the domains of livestock resources, infrastructure and the output. As a novel index, the ranking based on AHP is dependent on 12 parameters in comparison with the other

existing indexes like per capita availability, per capita production as shown in Table 4. Among the states, Punjab is leading the country in terms of per capita milk availability followed by Haryana and Rajasthan and their rank based on matrix is 8th, 9th and 4th respectively. In addition, the index is dynamic in which parameters can be modified according to requirement and variations in the local conditions and demands. Thus, new Dairy Index is an important aid in understanding the heterogeneity and complexity of the nation's performance in dairy. It is the first attempt at establishing an annual systematic tool for measurement of performance across states and UTs on a variety of dairy parameters within a composite measure.

To conclude, this study has introduced a novel index to better evaluate the dairy development using AHP that can be used by different stake holders for evaluating efficiency of existing systems, etc. The composite Dairy Index can promote a cooperative and competitive spirit among the states and UTs to rapidly bring about transformative action in achieving the desired outcomes. The same can be utilized over a period of years to capture the annual incremental progress on a variety of indicators. Though with the addition of more criteria, availability of more research information and technologies, the ranking of states could change with subsequent change in the inputs and improving the quantum and quality of data. Future studies can be conducted to standardize the model at the national level and explore its dimensions in evaluating, planning and implementing of various programmes.

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Selfing in *Buxus wallichiana* Baill.: a trait or strategy?

Plants of *Buxus wallichiana* are evergreen trees[1,2]; these are monoecious with male and female flowers aggregated together in a cyathium. In each inflorescence, a centrally placed female flower remains surrounded by 8–14 male flowers (Figure 1 *a*, *b*). Individual male flower is small, incomplete, zygomorphic and averages 5 mm in size. It consists of 4 basifixed anthers enclosed within 5 tepals (Figure 1 *c*). Female flower is slightly smaller than males and has an average size of 4.6 mm. It consists of 5 tepals enclosing a pistil comprising of a tricarpellary ovary and three short styles spread apart with the help of three nectariferous bulges. Each style terminates into bifid stigma (Figure 1 *d*). Ovary is syncarpous, 3 loculed and each locule has ovules attached to a central placenta. Stigma is wet and papillate.

Floral buds appear on the plants in the second week of September when the minimum and maximum temperature in area average 6.8°C and 20.4°C respectively. In October as the temperature lowers to a minimum of 5.4°C, some male flowers (2%) do open and shed pollen, but majority of flowers in an inflorescence including the solitary female flower remain closed (Figure 1 *b*). These flowers then undergo a period of dormancy for 4–5 months (Oct.–Feb./March) when the area of existence experiences heavy snowfall, with temperature dipping to an average of 3.8°C. These conditions prevail till the second week of March. Buds resume opening in the first week of April (average temperature 17.2°C). The male flowers open first indicating protandry. An individual male flower takes one day to expand its tepals thereby exposing the anthers that elongate their filaments (Figure 1 *e*). On day 3 of anthesis, anther dehiscence initiates. Simultaneously, the remaining male flowers also start opening. On day 6 of anthesis in an inflorescence, female flower initiates opening along with the remaining 2–3 male flowers surrounding it (Figure 1 *f*). Two lobes of each stigma keep appressed to each other till the female flower is closed. As the tepals expand completely, stigmatic lobes also start diverging. These take 2–3 days to expand completely. Anthers of the male flowers surrounding this female flower elongate by day 8, by this time the female flower is also completely open and the stigmatic lobes are spread. On day 9 anthers of the opened male flowers surrounding the female flower are positioned almost above stigma lobes, where