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Spatio-temporal analysis of bovine and ovine composition, and bovine milk production trend in Himachal Pradesh, India: District-wise analysis

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ABSTRACT

The Livestock Census-2017 estimated the total livestock population of Himachal Pradesh at 4.41 million, of which, 55% are bovines and 40.8% are ovines. District-wise analysis was performed for the period 2003 to 2017. During this period, the population of indigenous cattle had declined by 20.50%, while crossbred cattle increased by 20.73%. However, buffalo population remained almost unchanged and ovines declined by 6.41% during the same period. Milk production in the year 2018 was 1434 MT and average milk production was 1.91, 4.72 and 3.38 kg per day per animal in indigenous cows, crossbred cows and buffaloes respectively. Milk production increased by CAGR of 2.28%, 7.30% and 3.85% in indigenous cows, crossbred cows and buffaloes, respectively for the period 2003 to 2017. The increased bovine milk production in the state was mainly due to increasing population of crossbred cattle and increase in Lactating Efficiency (LE). The LE of crossbreed cattle was the highest (51%). The forecasted milk production in the state using Auto Regressive Integrate Moving Average model for the year 2030 is 2101 ('000) MT. To sustain and improve this milk production trend in Himachal Pradesh, necessary support services like a greater number of artificial insemination centers and veterinary clinics and ensuring better access to market should be created. The government should also make arrangements to procure surplus milk and export to other states and convert into milk products. This will help the dairy farmers to fetch better prices for their produce on a sustainable basis.

Keywords: Buffalo, Crossbred, Indigenous, Lactating efficiency, Milk Productivity, Nutritional demand

Livestock is a major component of agricultural sector which provides the livelihood for large number of rural medium, small and marginal farmers. Livestock provides livelihood to two-thirds of rural community and employment to about 9.2% of the population in India (20th Quinquennial Livestock Census Report 2017). Livestock is an important source of food and nutritional security and also provides draught power and manure inputs to the crop sub-sector and helps in generation of foreign exchange through exports (Birthal and Rao 2002). In India, livestock sector contributes 4.11% to Gross Domestic Product (GDP) and 25.69% of the total Agriculture GDP (DAHDF 2019). In the last few decades, the contribution of livestock sector to the national economy has been higher than that of the agriculture sector, which reflects the importance of this sector in India's economy. In 2018-19, India recorded milk production of 187.75 million MT achieving top rank in the world. As a result, the per capita availability of milk per day in India has grown to 394 g (NDDB 2019), which is much higher than the ICMR recommended level of 300 g.

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Himachal Pradesh, being a hilly state situated in the northern part of India is known for its agriculture, horticulture, hydropower and tourism. The livestock sector is also an important source of livelihood in the mountainous terrains of the State. The state has a total livestock population of 4.41 million which plays an important role in the State's livelihood with an annual milk production of 1434 MT and the per capita availability of milk of 565 g per day (DES 2019). In Himachal Pradesh, systematic studies on the trends of bovine and ovine populations and bovine milk production are scarce. Hence, the present study is an attempt in this direction.

MATERIALS AND METHODS

Data sources: District level data on bovine and ovine populations, bovines in milk, milk yield and milk production were collected for the period 2003 to 2017 for 12 districts of Himachal Pradesh. The study covered four livestock census and integrated sample surveys conducted by the Department of Animal Husbandry, Himachal Pradesh (DAHDF 2019).

Variables: The focus was on analyzing the trends in bovine milk production in relation to trends in bovine population and lactating efficiency, and forecasting the gap between demand and supply of milk using the past data.

Table 1. AIC values for selection of the best fitted ARIMA model for forecasting milk production of Himachal Pradesh

ARIM (*p, d, q*)	AIC
ARIMA(2,2,2)	335.78
ARIMA(0,2,0)	356.12
ARIMA(1,2,0)	345.88
ARIMA(0,2,1)	333.45
ARIMA(1,2,1)	333.59
ARIMA(0,2,2)	332.55
ARIMA(1,2,2)	334.46
ARIMA(0,2,3)	334.37
ARIMA(1,2,3)	336.21

Statistical analysis: The data on bovine milk production and the factors affecting it are not available for all the study periods. For example, the data on bovine population is available for every five years. Therefore, in order to link LE and milk yield with milk production, harmonization of data was necessitated. For this purpose, linear interpolation was employed. The formula used for this purpose is as follows:

If the known values are y_1 and y_2 and, then the y value for some point x can be given as:

$$Y = Y_1 + \frac{(X_2\text{-}X_1)\,(Y_2\text{-}Y_1)}{(X_2\text{-}X_1)}$$

where x_1, Initial year; x_2, End year; y_1, Initial year value; and y_2, End year value.

Compound annual growth rate: In order to analyze the trends in milk production, bovine population and milk yield, the Compound Annual Growth Rates (CAGR) were worked out as below:

$$\text{CAGR} = \frac{(\text{Value of variable in ending year} - \text{value of variable in initial year})}{(\text{Value of variable in starting year} \times \text{number of years})} \times 100$$

Lactating efficiency: LE was defined as the ratio of in-milk to total adult females for each bovine species (Chauhan 1995) and is computed as follows:

$$\text{LE} = \frac{(\text{Number of bovines in-milk})}{(\text{Total adult females})}$$

Forecasting of milk production

ARIMA model: Auto Regressive Integrate Moving Average (ARIMA) model is the most widely used approach to time series forecasting. ARIMA modeling (Box and Jenkins 1976) uses previous time series data plus an error to forecast future values. More specifically, it combines a general autoregressive model AR (*p*) and general moving average model MA (*q*):

- AR (*p*) — uses previous values of the dependent variable to make predictions.
- MA (*q*) — uses the series mean and previous errors to make predictions.

Mathematically, an autoregressive model of order *p* can be represented as

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \ldots\ldots + \phi_p y_{t-p} + a_t$$

where, $\phi_{1\ldots\ldots}\phi_p$, parameters; *d,* degree of differencing involved to make the data series that contains a trend (non-stationary) to stationary by taking successive differences of the data; *q*, order of the moving average process in which the dependent variable y_t depends on the values of error term (a_t, a_{t-1}... a_{t-p}) rather than the variable itself.

Mathematically, a moving average model of order *q* can be expressed as

$$y_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \theta_3 a_{t-3} - \ldots\ldots\ldots - \theta_q a_{t-q}$$

where $\theta_{1,}\theta_{2,\ldots\ldots}\theta_q$, parameters; a_t, error residual and a_1, $a_{2,\ldots\ldots}$ a_{t-q} , previous values of error.

The parameters *p, d* and *q* can be estimated by maximum likelihood method (MLE).

Implementation of ARIMA model: The annual data of milk production across the districts was collected and used for forecasting the future values using ARIMA models for the period 2018-19 to 2029-30. ARIMA(0,2,2) was the best fitted model based upon the lowest value of Akaike's Information Criteria (AIC) (Table 1). The Autocorrelation Functions (ACFs) and Partial Autocorrelation Functions (PACFs) of the residuals for the fitted ARIMA (0,2,2) from lag 1 to lag 16 are within the significance limits (Fig. 1). Box-Ljung test value (Chi-square value =12.65, P>0.05) being not statistically significant also favours to accept the null hypothesis that all of the ACFs between the lags are zero. Thus, it can be concluded that there is no evidence for non-zero autocorrelations in the forecast errors between lags.

Estimation of demand for milk: The formula used by Chuahan (1995a) for estimating the demand for milk is as follows.

$$Y = X_1 \times X_2 \times X_3$$

where Y, Demand for milk per year in kilogram (kg); X_1, Human population in million; X_2, 300 gram per day (ICMR nutritional recommendation of milk); and X_3, 365 days.

The projected human populations of Himachal Pradesh up to the year 2030 were obtained from NCP (2019), worked out based on fertility, mortality and migration rates.

RESULTS AND DISCUSSION

Trends in crossbred cattle population: In Himachal Pradesh, the crossbred cattle population was 0.65 million in 2003, which increased to 1.07 million in 2017, with a CAGR of 3.36% (Table 2). In Hamirpur, the population of crossbred cattle decreased marginally with CAGR of -0.91% and overall 12% decline in crossbred population occurred. Highest CAGR was found in districts of Chamba, Una and Sirmour with 5.48%, 5.28% and 5.07% respectively.

Trends in indigenous cattle population: The indigenous cattle population in 2003 was 1.54 million, which decreased to 0.7 million in 2017 with CAGR of -4.45% (Table 2). In different districts of the state, the trends in indigenous cattle population were similar to the trends observed in

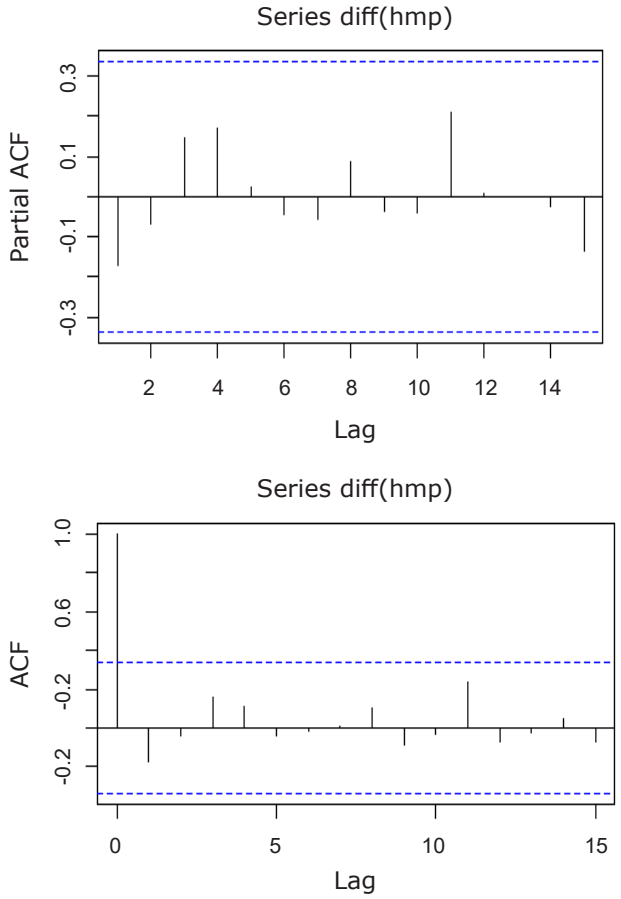

Fig. 1. Estimated PACF and ACF of residuals for the fitted ARIMA (0, 2, 2).

the state, i.e. maximum negative growth rate (CAGR) was found in Hamirpur, Una and Kangra districts, (i.e. -14.20%, -10.48% and -8.20%, respectively).

Trends in buffalo population: Buffalo population in the state was 0.77 million in 2003, which registered a decreasing trend and reached 0.64 million in 2017, with CAGR of -1.17% (Table 2). The trends across the study districts were found similar to the trend of state. Shimla, Chamba and Sirmour districts recorded the highest CAGR, i.e. -6.86%, -3.36% and -2.10% respectively. However, in districts Kinnaur, Kullu and Bilaspur, there was a positive trend in buffaloes.

Trends in ovine population: Ovine population in the state was 4.9 million in 2003 which decreased and reached 4.4 million, with CAGR of 0.77% (Table 2). The trends across the districts were found similar to trends of state, but in the district of Kinnaur, positive growth (3%) was found. Highest decline in population of ovine was found in the districts of Lahul-Spiti, Shimla, Mandi and Solan with 34%, 18%, 17.34% and 17.18%, respectively.

The findings of this study are in conjunction with that of Chauhan (1995b), who reported that the indigenous cattle population in the state had decreased due to the higher production efficiency of crossbred cattle. Khalandar *et al*. (2019) on analyzing the trends in cattle and buffalo population in Karnataka, also reported that the population of indigenous cattle and buffaloes declined, whereas the crossbred cattle population continued to increase due to higher economic and technical efficiency. Sserunjogi and Kaur (2016), while analyzing the livestock data of India, reported that the bovine population was largely dominated by indigenous cattle and later declined.

Trend in milk production across the districts of Himachal Pradesh: The total milk production in Himachal Pradesh during 2003 was 772.47 thousand tonnes, which increased to 1392 thousand tonnes in 2017, registering a total growth of 80% with CAGR of 4.00% (Table 3). In districts of Kullu, Mandi, Shimla and Una, a positive per cent change was found. Milk production contribution from crossbred cattle was continuously on the rise, because of higher productivity and good management practices. The increasing share of milk production from crossbreds could largely be attributed to increasing adoption of crossbred animals by the farmers due to higher productivity. Further, the changing farm practices from manual to mechanization in crop sector might have led to decreasing indigenous cattle, thereby reducing the share of milk production from these cattle. This reason may also apply to some extent, for decreasing contribution of milk production from buffaloes.

Lactating efficiency: The LE of indigenous cattle in 2007 was 0.38, which increased to 0.42 in 2017, with an overall increase of 11.59%. The growth rate in lactating efficiency of indigenous cattle showed a small increase across the districts. However, Hamirpur and Kinnaur districts registered a negative trend in lactating efficiency. In comparison to the crossbred cattle and buffaloes, the indigenous cattle registered the lowest lactating efficiency across the districts in different census periods. The results for lactating efficiency in indigenous cattle showed that a significant proportion of female population was dry, which is ultimately leading to unwillingness of the dairy farmers to rear these animals (Supplementary Table 1).

Crossbred cattle: The in-milk female crossbred cattle showed a consistent positive growth, so LE of crossbred cattle showed a positive and increasing trend across the state. The LE of crossbreed cows was higher, because of genetically improved traits for milk production. Initially LE was 0.36 and increased to 0.51 in 2017 (Supplementary Table 1).

Buffalo: The LE of buffaloes showed a negative and declining trend, and it was 0.48 in 2007 and 0.42 in 2017, which led to replacement of low yielding buffaloes with high yielding crossbred cattle and high yielding buffaloes. In the districts of Kinnaur and Lahul and Spiti, population of buffalo was very low. Highest decline (0.74–0.34) in LE was observed in Shimla district, with highest increase of LE (0.16–0.84) in Kullu district (Supplementary Table 1).

All India results indicated that crossbred cattle registered the highest lactating efficiency, followed by buffaloes in all the census periods. The observed trend could have resulted from increased replacement of low-yielding indigenous cattle with crossbred and buffaloes (Sserunjogi and Kaur 2016). Birthal *et al.* (2012) also observed that the rapid

Table 2. Temporal analysis and growth rate of bovine and ovine population in different districts of Himachal Pradesh

District	Year	Crossbred cattle		Indigenous cattle		Buffaloes		Ovines	
		Population (No.)	CAGR	Population (No.)	CAGR	Population (No.)	CAGR	Population (No.)	CAGR
Bilaspur	2003	21101		32845		97668		55813	
	2007	19974	-1.09	33030	0.11	100069	0.48	77369	2.12
	2012	26170	4.60	21722	-6.74	100586	0.0985	60667	-1.60
	2017	31767	3.28	13009	-8.18	99514	-0.178	75128	-1.28
Chamba	2003	27994		262858		41432		466198	
	2007	34260	4.12	282996	1.48	39434	-0.98	557129	2.73
	2012	50746	6.76	262448	-1.24	32465	-3.18	459440	-2.08
	2017	62366	3.49	199573	-4.46	24794	-4.39	466129	-1.36
Hamirpur	2003	20596		18444		104512		47552	
	2007	19836	-0.74	13549	-5.98	113921	1.7439	44548	-5.40
	2012	23402	2.79	3856	-18.89	108083	-0.87	33697	-6.651
	2017	17937	-4.33	1852	-11.50	97246	-1.74	31194	-4.266
Kangra	2003	153011		243546		162695		316713	
	2007	172920	2.47	207968	-3.10	156093	-0.82	264908	-1.75
	2012	222247	4.27	136882	-6.73	149719	-0.692	287322	-0.11
	2017	229407	0.52	66552	-11.32	133697	-1.86	317298	0.31
Kinnaur	2003	9346		13787		9		109021	
	2007	11103	3.50	10990	-4.43	148	75.06	100658	-1.44
	2012	11971	1.26	9586	-2.25	720	30.17	99836	-0.20
	2017	15576	4.48	6919	-5.28	1301	10.36	124046	2.03
Kullu	2003	63660		13787		313		207938	
	2007	90260	7.23	10990	-0.09	872	22.74	184477	0.16
	2012	95372	0.92	9586	-5.40	720	-3.14	192639	-0.80
	2017	115056	3.17	6919	-10.76	1002	5.66	191922	-0.52
Lahul-Spiti	2003	7157		6144		0	-	52017	
	2007	6869	-0.81	5645	-1.67	0	-	45447	-2.36
	2012	7969	2.50	5228	-1.27	3	-	44210	-0.15
	2017	7518	-0.96	4160	-3.73	10	-	26458	-4.71
Mandi	2003	136190		301346		84301		319589	
	2007	199752	7.96	286143	-1.03	81643	-0.63	367322	2.12
	2012	223403	1.88	216364	-4.55	69320	-2.69	309418	-2.19
	2017	228783	0.39	130513	-8.07	63856	-1.35	280920	-2.67
Shimla	2003	100778		206409		16292		196599	
	2007	118955	3.37	185611	-2.10	13793	-3.27	186245	-0.60
	2012	145223	3.38	131560	-5.57	9189	-6.54	204663	-0.46
	2017	143203	-0.23	76973	-8.54	5603	-7.91	185780	-2.47
Sirmour	2003	38640		209405		50675		156584	
	2007	45378	3.26	217020	0.71	49829	-0.63	208644	2.12
	2012	66860	6.67	212265	-0.36	42907	-2.69	156035	-2.19
	2017	81215	3.29	164482	-4.16	36838	-1.35	140155	-2.67
Solan	2003	47118		107452		90787		71801	
	2007	49846	-2.67	94298	2.33	84071	-6.60	84229	-0.29
	2012	71123	1.13	73927	-2.57	79937	-1.52	62805	-1.36
	2017	81677	6.10	49059	-3.97	70674	-2.03	48184	-1.50
Una	2003	25152		32291		124545		21789	
	2007	23828	-1.07	28198	-2.67	121716	-0.45	21159	-0.88
	2012	39442	8.76	12154	-13.08	123087	0.18	13630	-0.57
	2017	54430	5.51	5937	-11.25	113042	-1.40	12544	0.76
Himachal	2003	650743		1545795		773229		2021614	
	2007	792981	4.00	1476197	-0.9217	761589	-0.30	2142135	1.64
	2012	983928	3.60	1165331	-3.86	716736	-1.02	1924362	-1.77
	2017	1068935	1.40	759082	-6.89	647577	-1.68	1899758	-0.21

Table 3. Trends in milk production across the districts of Himachal Pradesh

District	Year	Milk production ('000 MT)	%AGR	%CAGR
Bilaspur	2003	35.11		
	2007	53.87	10.68	8.93
	2012	69.81	4.93	4.41
	2017	79.83	2.38	2.24
Chamba	2003	61.27		
	2007	63.68	0.78	0.77
	2012	79.75	4.20	3.82
	2017	91.14	2.37	2.24
Hamirpur	2003	60.33		
	2007	64.81	1.48	1.45
	2012	85.33	5.27	4.68
	2017	92.83	1.46	1.41
Kangra	2003	143.94		
	2007	187.32	6.02	5.40
	2012	222.29	3.11	2.89
	2017	247.97	1.92	1.83
Kinnaur	2003	6.38		
	2007	8.33	5.70	5.15
	2012	9.94	3.21	2.98
	2017	12.91	4.98	4.45
Kullu	2003	30.41		
	2007	49.37	12.46	10.17
	2012	82.47	11.177	8.92
	2017	95.69	2.67	2.50
Lahul-Spiti	2003	6.91		
	2007	6.55	-1.07	-1.05
	2012	6.98	1.17	1.08
	2017	9.06	4.96	4.44
Mandi	2003	120.63		
	2007	136.51	2.63	2.50
	2012	211.79	9.10	7.59
	2017	260.46	3.82	3.50
Shimla	2003	79.25		
	2007	98.64	4.89	4.47
	2012	122.12	3.96	3.62
	2017	162.88	5.56	4.59
Sirmour	2003	71.82		
	2007	70.83	-0.27	-0.28
	2012	78.63	4.87	4.36
	2017	99.83	4.49	4.05
Solan	2003	73.78		
	2007	77.91	1.11	1.09
	2012	90.29	2.64	2.48
	2017	130.48	7.41	6.32
Una	2003	72.68		
	2007	65.64	-1.93	-2.01
	2012	79.18	3.43	3.17
	2017	109.07	6.27	5.47
Himachal	2003	772.47		
	2007	873.47	2.61	2.48
	2012	1138.61	6.07	5.44
	2017	1392.09	4.45	4.10

growth in productivity of dairy bovines could be attributed to the technological change, better feeding practices and improvements in animal health. Khalandar *et al.* (2019) also reported an increasing trend in the lactation efficiency in Karnataka in bovines which was mainly due to the improvement in management practices, and LE of buffalo and indigenous cattle was increased by replacement of old female and male population with adult female population.

Forecasted gap in supply and demand of milk: Based on forecasted long-term trends using ARIMA model, the milk production in Himachal Pradesh is expected to go up to 2101.50 ('000) MT by the end of year 2030 which exceeds the estimated demand of 841.51 ('000 MT). Thus, the estimated surplus milk in the state will be 1259.99 ('000) MT (Supplementary Table 2).

Analysis of bovine and ovine population in Himachal Pradesh over 20 years revealed that the indigenous cattle population was decreasing, mainly due to rearing of more and more of highly productive crossbred cattle and increasing mechanization in crop sector. The share of milk production from the both indigenous cattle and buffaloes is declining due to poor lactating efficiency, less productivity and seasonal breeding in buffaloes. However, the share of crossbred population across all districts of the state was increasing significantly over the census due to their higher productivity. Though the productivity of the crossbred population in Himachal Pradesh is increasing, it still remains less than the national average. The reason for this scenario is that the majority of the land area of the state is hilly and temperate which leads to scarcity of green fodder throughout the year. Therefore, the Department of Animal Husbandry should make arrangements to purchase feed and fodder from plains and supply them in hilly areas during winters. This will help the individual dairy farmers to purchase feed and fodder at relatively lesser prices. Artificial insemination services in hilly regions need to be extended significantly to improve the milk production. This study has estimated significant quantity of milk surplus for years to come. Therefore, the government should also make arrangements to procure surplus milk and export to other states and convert into milk products. This will help to keep up the demand for milk and thereby the dairy farmers can fetch better price for their produce on a sustainable basis.

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