Modeling and Forecasting Livestock Feed Resources in India Using Climate Variables

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ABSTRACT : The availability and efficient use of the feed resources in India are the primary drivers to maximize productivity of Indian livestock. Feed security is vital to the livestock management, extent of use, conservation and productivity enhancement. Assessment and forecasting of livestock feed resources are most important for effective planning and policy making. In the present study, 40 years of data on crop production, land use pattern, rainfall, its deviation from normal, area under crop and yield of crop were collected and modeled to forecast the likely production of feed resources for the next 20 years. The higher order auto-regressive (AR) models were used to develop efficient forecasting models. Use of climatic variables (actual rainfall and its deviation from normal) in combination with non-climatic factors like area under each crop, yield of crop, lag period etc., increased the efficiency of forecasting models. From the best fitting models, the current total dry matter (DM) availability in India was estimated to be 510.6 million tonnes (mt) comprising of 47.2 mt from concentrates, 319.6 mt from crop residues and 143.8 mt from greens. The availability of DM from dry fodder, green fodder and concentrates is forecasted at 409.4, 135.6 and 61.2 mt, respectively, for 2030. (**Key Words :** Feed Resources, Forecasting Models, Auto-Regressive, Climate Variables, DM, Concentrates)

INTRODUCTION

Agriculture is the main occupation in India, and about 60% of the population is engaged in this activity. The net cultivated area is about 142 million hectares, and livestock rearing is an integral part of the various farming systems, with 304.7 million bovine population and 215.7 million sheep and goats. Arable agriculture contributes a major fodder resource in the form of crop residues, which are extensively fed to the animals. The area under fodder crops amounts to 4.75% (8.9 million hectares) of the total cultivated area. The total area of permanent pastures and grasslands is about 12.8 million hectares. An area of 15.6 million hectares, classified as waste land, is also used for grazing. Forests, and their associated grasslands and fodder trees, are another major source of grazing and fodder collection (Singh et al., 2004; Mishra, 2005).

The animal species raised include the cattle, buffalo, sheep, goats, horses, pigs and poultry, besides some less common species such as yak, camel and mithun. One of the notable characteristics of the Indian livestock sector is that,

almost its entire feed requirement is met from crop residues and byproducts, grasses, weeds and tree leaves and grazing on common lands and harvested fields (Dikshit and BIRTHAL, 2010). More reliance on crop residues with a low nutrition level does not produce optimum output. Consequently, larger numbers of livestock are kept for producing the required milk, meat and work purposes of their owners. If healthy and well-fed animals are used with improved equipment and processes, India can get increased output from a lesser number of livestock, thus reducing the burden on land (World Bank, 1999; Mishra et al., 2007).

Feed scarcity is the main limiting factor to improving livestock productivity and for example, the actual milk yield of bovines is reported to be 26 to 51 per cent below the attainable yield under field conditions (BIRTHAL and JHA, 2005). Hence, proper assessment and efficient management of available feed resources are vital to improve the productivity of animals and also, the socioeconomic development of the country. It also helps the planners to make appropriate decisions at the right time. The quality of the decision largely depends on the quality of the forecast (De Lurgio and Bhame, 1991; Jain, 1996). The major use of forecasting, as it relates to modeling, is to predict the value of a model's variables as well as the logical relationships of the model at some time in the future. There are three types

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of forecasts: i) short-term (up to one year) forecasts, which are used mainly in deterministic (certainty) models; ii) Intermediate term (one to three years) forecasts; and iii) long-term (beyond three years) forecasts, which are used in both deterministic and probabilistic models. The present paper focuses on modeling and forecasting of livestock feed resources, using probabilistic models such as Autoregressive (AR), to study the influence of climatic and non-climatic variables on the availability of feed resources.

MATERIALS AND METHODS

Study area and data collection

The assessment and forecasting of feed resources for livestock was carried out for the entire country. India, the seventh largest country in the world, lies between latitudes 8° and 37° N and longitudes 68° and 97° E and occupies a geographical area of 329 million hectares. The country exhibits great diversity in climate, topography, flora, fauna and land use. The precipitation ranges from 150 mm in western and north-western desert to about 9,000 mm in Meghalaya in the north-east. The temperature ranges from sub zero in the Himalayas to about 50°C in the central and western parts.

The secondary data on area and production of cereals, pulses, oilseeds, and land use (gross cropped area, acreage under fodder crops, forests, permanent pastures and grazing land, cultural waste land and current fallows) were collected from the Department of Economics and Statistics, Animal Husbandry department, Government of India and Indian Harvest from Center for Monitoring Indian Economy (CMIE) for the period of 1970 to 2010. The data on climate variables (rainfall and its deviation from normal) were collected from CMIE.

Categories of feed resources

According to Devendra (1997), three major categories of feeds are: i) Pastures and forages - these include native and improved grasses, herbaceous legumes and multi-purpose trees ii) Crop residues (dry fodder) - cereal straws, stovers, groundnut haulms etc. iii) Agro-industrial by-products - good examples are cereal bran, coconut cake, palm kernel cake, soya bean, meal, molasses, distillers dried grains. The availability of dry fodder, greens and concentrates was calculated using a suitable extraction ratio, also called as residues to product ratio (RPR). The coefficients used for conversion in the present study are given in Table 1 (Agriculture Statistics at glance, 2008).

The quantum of green fodder, dry fodder and concentrate feed was converted into dry matter (DM) by applying a factor of 0.25 for green fodder, and 0.90 for dry fodder and concentrate feed. The factors for conversion of DM from each source into total digestible nutrients (TDN)

were taken as 0.534 for green fodder, 0.476 for dry fodder, and 0.780 for concentrate feed. The factors for conversion of DM from each source into crude protein (CP) were 0.073, 0.016 and 0.180 for green fodder, dry fodder and concentrate feed, respectively (Dikshit and Birthal, 2010). The major fodder crops like maize, sorghum, pearl millet, Egyptian clover, Lucerne, cluster bean etc., were considered. The area under fodder crops was calculated to be 8.9 million ha, and the fodder productivity was estimated by using the weighted average of 40.93 tonnes/ha, considering the minimum yield of each fodder crop (Hand book of Agriculture, 2005). The weighted average was calculated by using the formula

$$\bar{x} = \frac{x_1 w_1 + x_2 w_2 + \dots + x_k w_k}{w_1 + w_2 + \dots + w_k}$$

where $x_1, x_2, \dots, x_k$ are yields of different fodder crops and $w_1, w_2, \dots, w_k$ are weights attached to each fodder crop. Weight for each fodder crop is the proportion of area under crop, to the total area under fodder crops.

Statistical analysis

In order to assess and forecast the feed resources availability for better management of livestock, linear time series models were developed by using Time Series Forecasting System (TSFS) of SAS 9.2 (SAS, 2009). Higher-order auto-regressive (AR) models with lags ranging from 1 to 19 were developed, with climatic and non-climatic factors as regressors. The climatic factors considered in the models were actual rainfall and the deviation of rainfall from normal. The non-climatic factors such as yield, area under crop etc., were also included in the models. Autocorrelation function plot (ACF) was performed to detect the presence of autocorrelation in the data and identify the order of time lag to account for it in modeling. Normalized plots of residuals and plots of standardized versus predicted values were examined as part of diagnostic phase of modeling to assess normality distribution of residuals and homogeneity of variance over the time respectively. The canonical form of full model used for various crop yields is

$$Y_t = \theta_0 + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \phi_3 Y_{t-3} + \dots + \theta_1 \text{rainfall} + \theta_2 \text{rainfall deviation} + \theta_3 \text{AUC} + \theta_4 \text{Yield} + \varepsilon$$

Where, $Y_{t-1}, Y_{t-2}, Y_{t-3}, \dots$ are past data at time $t-1, t-2, \dots$, $\phi_1, \phi_2, \phi_3, \dots$ and $\theta_1, \theta_2, \theta_3, \dots$ are the co-efficient of auto-regressive models, AUC is the Area under crop, Yield is the yield of crop per hectare, and ε is the error component. The best model was selected based on Root Mean Square Error (RMSE) and Co-efficient of determination (R^2) values (Box and Jenkins, 1976).

Table 1. Residues to product ratio (RPR) used in the assessment of livestock feed resources

Category of feed sources	Residues to product ratio				
	Crop residues	Grains	Bran/hull	Oilcakes	Green fodder (t/ha)
Straws and stovers					
Rice (<i>Oryza sativa</i>)	1.30	0.02	0.08	-	-
Wheat (<i>Triticum aestivum</i>)	1.00	0.02	0.08	-	-
Bajra (<i>Pennisetum typhoides</i>)	2.50	0.05	-	-	-
Finger millet (<i>Eleusine coracana</i>)	2.00	0.05	-	-	-
Maize (<i>Zea mays</i>)	2.50	0.40	-	-	-
Sorghum (<i>Sorghum bicolor</i>)	2.50	0.05	-	-	-
Small millets (<i>Panicum miliare</i> , <i>P. miliaceum</i> , <i>Setaria italic etc.</i>)	2.50	0.10	-	-	-
Tubercrops					
Cassava (<i>Mannihot esculenta</i>)	-	0.12*	-	-	-
Pulses					
Gram (<i>Cicer arietinum</i>)	1.7	-	0.03	-	-
Red gram (<i>Cajanus cajan</i>)	1.7	-	0.03	-	-
Other pulses	1.7	-	0.03	-	-
Oilseeds					
Groundnut (<i>Arachis hypogaea</i>)	2.00	-	-	0.60	-
Soya bean (<i>Glycine max</i>)	1.60	-	-	0.73	-
Linseed (<i>Linum usitatissum</i>)	-	-	-	0.67	-
Rapeseed and mustard (<i>Brassica sps.</i>)	-	-	-	0.67	-
Sunflower (<i>Helianthus annus</i>)	-	-	-	0.70	-
Safflower (<i>Carthamus tinctorius</i>)	-	-	-	0.70	-
Niger seed (<i>Guizotia abyssinica</i>)	-	-	-	0.72	-
Sesamum (<i>Sesamum usitatissum</i>)	-	-	-	0.60	-
Coconut (<i>Cocos nucifera</i>)	-	-	-	0.056	-
Cotton (<i>Gossypium sps.</i>)	-	-	-	0.049	-
Castor (<i>Ricinus communis</i>)	-	-	-	0.50	-
Greens					
Sugarcane (<i>Saccharum officinalis</i>)	-	-	-	-	0.25**
Gross cropped area, excluding the area under fodder crops (2.024% of gross cropped area)	-	-	-	-	5.0
Area under fodder crops	-	-	-	-	40.93***
Forest area	-	-	-	-	1.50
Permanent pastures and grazing land	-	-	-	-	5.00
Land under misc. tree crops and groves not included	-	-	-	-	1.00
Cultural wasteland	-	-	-	-	1.00
Current fallow	-	-	-	-	1.00
Other fallow	-	-	-	-	1.00

Source: Agricultural statistics at a glance, 2007, Directorate of economics and statistics, Ministry of Agriculture, GOI.

* Srinivas, T. and M. Anantharaman. (2005). ** Sugarcane top to cane ratio.

*** Weighted average estimated from the yields as per Hand Book of Agriculture, 2005.

RESULTS AND DISCUSSION

Best fitting models

The data on production of 23 crops for 40 years, along with climatic and non-climatic factors were used to develop the time series forecasting models. The best fitting models were assessed based on minimum value of RMSE, and the maximum value of R^2 . Two climatic factors i.e., actual rainfall, and its deviation from normal were used in the models. The non-climatic variables such as temporal factors (trend, seasonality, cyclical and other fluctuations), lag period (serial correlation or successive dependence of data), area under crop, and crop yield (to account for the improvement in management practices and technology) were also considered in the model development. The time lag period was maximum (19 years) for sunflower, and minimum (one year) for cassava. The climatic and non-climatic factors were significant ($p < 0.05$) for most of the crops. The characteristics of higher order auto-regressive models with different time lag periods to account for the variation due to serial correlation, and other variables for different crops are given in Table 2, and depicted in Figure 1.

The best fitting models for different types of land use pattern (Table 3, Figure 1) were: linear trend for gross cropped area; linear (Holt) exponential smoothing for the land uses like forest, permanent pastures and grazing; log linear (Holt) exponential smoothing for the area under miscellaneous tree crops and groves; higher order auto-regressive for current fallows, other fallows and the area under fodder crops. Actual rainfall and its deviation from normal were significant ($p < 0.05$) for both types of fallows, and the area under fodder crops.

The auto-regressive models are more efficient than simple linear regression models for longitudinal data. To exploit the cross-sectional and temporal attributes of data sets, auto-regressive models were developed for each crop. This method is appropriate for longitudinal data (Pinheiro and Bates, 2000; Zuur et al., 2009), where observations within a group are more often similar, than when predicted on a pooled data basis. The simple linear regression ignores the grouping effect and violates the assumption of independence of observations. In a similar type of study in Tanzania, Pedram Rowhani et al. (2011) relied only on the first order autoregressive models to capture the serial correlation structure. However, in the present work, time lag

Table 2. Summary of Autoregressive forecasting models for crop production with various regressors

Sl no.	Crop	Lag period in autoregressive models	Actual rainfall	Rainfall deviation from normal	Area under crop	Yield	R^2 (%)	RMSE
1	Rice	10	0.097+	0.091+	<0.001**	<0.001**	99.9	0.434
2	Wheat	5	0.586	0.910	<0.001**	<0.001**	99.9	0.649
3	Bajra	3	0.734	0.343	<0.001**	<0.001**	99.4	0.146
4	Sorghum	9	0.273	0.301	<0.001**	<0.001**	98.3	0.249
5	Finger millet	5	0.232	0.069+	<0.001**	<0.001**	96.7	0.067
6	Small millets	10	0.121	0.056+	<0.001**	<0.001**	99.3	0.042
7	Maize	9	0.489	0.616	<0.001**	<0.001**	99.7	0.208
8	Bengal gram	14	0.421	0.002**	<0.001**	<0.001**	99.8	0.039
9	Red gram	5	0.822	0.077+	<0.001**	<0.001**	99.6	0.023
10	Other pulses	14	0.246	0.012*	<0.001**	<0.001**	99.9	0.027
11	Groundnut	17	0.560	0.173	<0.001**	<0.001**	99.8	0.068
12	Soyabean	-	-	-	-	-	94.4	0.801
13	Linseed	6	0.117	0.168	<0.001**	-	93.5	0.032
14	Rapeseed and mustard	14	0.001**	0.003**	<0.001**	<0.001**	99.5	0.138
15	Sunflower	19	<0.001**	<0.001**	<0.01**	<0.001**	99.3	0.037
16	Safflower	17	<0.001**	<0.001**	<0.01**	<0.001**	99.1	0.011
17	Nigerseed	16	0.337	0.703	<0.001**	<0.001**	99.6	0.002
18	Sesamum	10	0.948	0.988	<0.001**	<0.001**	99.0	0.011
19	Sugarcane	10	0.555	0.305	<0.001**	<0.001**	99.9	2.04
20	Coconut	13	0.670	0.656	<0.001**	<0.001**	99.8	1.31
21	Cassava	1	0.728	0.375	<0.001**	<0.001**	99.9	49.72
22	Cotton	12	<0.001**	<0.001**	<0.001**	<0.001**	99.8	0.206
23	Castor	12	0.166	0.164	<0.001**	<0.001**	99.9	0.025

Data of previous 40 years, 1970-2010, used to construct models; R^2 , Co-efficient of determination; RMSE = Root mean square error.

+ Suggestive of significance, * and ** Significance at 5% and 1% respectively.

Figure 1. Graphs showing the best fitted auto-regressive models for forecasting crop production till 2030 (Selected crops).

period was extended further back till the complete capture of the serial correlation structure, and hence, these well developed models are more efficient for prediction of feed resources.

Two climatic factors, actual rainfall, and its deviation from normal, were used as regressors in the auto-regressive models. Both were significant ($p < 0.05$) for most of the oilseeds (sunflower, safflower, cotton and rapeseed & mustard) and pulse crops like Bengal gram. These factors, though not statistically significant for the remaining crops,

have very low probability (p) value, indicating their potential contribution in the models. Hence, the auto-regressive models obtained are more efficient when rainfall variability is included for forecasting feed resources. Several studies have shown that change in climatic parameters affects the agricultural production. Droughts, floods, heavy precipitation events and heat waves are known to negatively impact agricultural production (Naresh Kumar et al., 2011). Fluctuations in rainfall have widespread effects on each stage of crop management,

Figure 1. Graphs showing the best fitted auto-regressive models for forecasting crop production till 2030 (Selected crops). (Continued)

starting from seedbed preparation until harvest (Hollinger, 1994). The non-climatic factors, such as, area under crop and yield of crop were also studied for their effect by using the auto-regressive models. These factors are significant ($p < 0.001$) across all the crops, and inclusion of them enhanced the predictive efficiency of models. This empirical study is first of its kind to document effects of climatic and non-climatic factors on livestock feed resources availability in India.

Significance of non-climatic factors in the auto-

regressive models indicate the variability associated with change in managerial practices and/or technological progress in agriculture over the years. Most of the previous studies either used time as the only factor to represent temporal changes, or, climatic factors along with time, in developing the models (Wheeler et al., 2000; Challinor et al., 2005; Porter and Semenov, 2005; Pedram Rowhani et al., 2011). The present study attempts to capture the variation due to these factors in the model building. Failure to allow these specific characteristics may result in inferior

Table 3. Summary statistics for forecasting pattern of land use

Sl no.	Land use	Model used	Actual Rainfall	Rainfall deviation from normal	R ² (%)	RMSE
1	Gross area grown excluding area under fodder crops	Linear trend	-	-	83.9	3.76
2	Area under fodder crops	Autoregressive with 13 lag periods	0.927	0.377	52.0	0.442
3	Forest area	Linear Holt Exp smoothing	-	-	95.3	0.330
4	Permanent pastures and grazing land	Linear (Holt) Exponential smoothing	-	-	98.3	0.106
5	Land under misc. tree crops and groves not included	Log linear (Holt) exponential smoothing	-	-	72.4	0.137
6	Cultural wasteland	Damped trend exponential smoothing	-	-	97.9	0.219
7	Current fallow	Autoregressive with 13 lag periods	0.271	0.002**	60.0	1.256
8	Other fallow	Autoregressive with 10 lag periods	0.080+	0.019*	75.7	0.336

Data of previous 40 years, 1970-2010, used to construct models; R², Co-efficient of determination; RMSE = Root mean square error.

+ Suggestive of significance, * and ** Significance at 5% and 1% respectively.

forecast of aspects of interest, and results in inaccurate estimates of feed resource availability.

Assessment of feed resources

Assessment of livestock feed resources is the main focus of this study. The standard conversion factors like straw to grain ratio, cake to grain ratio etc were used to estimate the availability of dry fodder and concentrates (Table 1). The straw/stover to grain ratio for cereals varied between 1 and 2.5. Among cereal grains, the proportion used for feed purposes is maximum for maize (40%) and minimum for rice and wheat (2%). In case of Cassava, 12% of tuber production is used for livestock feed (Srinivas and Anantharaman, 2005). Pulse husks or legume hulls, a by-product of pulse milling industries is a source of animal feed and 3% of pulse production contributes to husk. Among the oilseed cakes, the contribution from soya bean is the maximum (73%). For sugarcane, 25% of cane production is considered in the calculation of greens. Among various other sources of green fodder, the productivity varied between one to 40.93 tons per hectare.

The standard conversion factors like straw to grain ratio, cake to grain ratio etc., were used to estimate the availability of dry fodder and concentrates. In some of the earlier studies (e.g., Ramachandra et al., 2007), similar conversion factors were used for estimating the availability of feed resources. The contribution from cassava is included in the present study, as the byproducts obtained during flour extraction from cassava are being widely used as cattle feed. The area under fodder crops has marginally increased from 6.9 million hectares in 1970 to 8.9 million hectares in 2011. The conversion factors used for estimating fodder crop yields were obtained by using the weighted average method,

taking into consideration, yield and area under different fodder crops (Hand Book of Agriculture, 2005), with an average yield of 40.93 tonnes/ha. Ramachandra et al. (2007) estimated the greens availability from fodder crops by assuming that 4% of gross cropped area is under fodder crops. In a study by Jain and Shivatar singh (1990), the availability of feed resources was quantified by merely assuming the conversion factors for crop residues and greens. The inclusion of fodder crops and cassava has increased the total feed resources availability by 80 mt in the present study.

There is a decreasing trend in the forest area, permanent pastures and grazing land, land under miscellaneous tree crops, cultural waste land and fallows and it has a greater negative impact on the dry matter availability from greens. Natural pastures are most commonly utilized feed resources in India and contribute significant amount of feed. However, the contribution and productivity of pasture lands is declining with time, mainly due to their diversion for other purposes, and thus reducing the total feed resources availability for livestock (Misra et al., 2007).

Forecasting of feed resources

Forecasting of feed resources is the third important aspect, after modeling and assessment as forecasts are useful to policy makers for contingency planning in the country. Feed resources availability from dry fodder, greens and concentrates were forecasted by using best fitted models developed for this purpose. Forecasting up to 2030 was done in this study (Table 4, Figure 1). The availability of dry fodder from crop residues increased from 160.8 mt in 1970 to 296.2 mt in 2010, and is predicted to jump further to 409.4 mt by 2030. Similarly, the production of

Table 4. Assessment and forecasting the livestock feed resources in India on dry matter basis (in million tons)

Feed resources	1970	1980	1990	2000	2005	2010	2011	2012	2013	2014	2015	2020	2025	2030
Dry fodder	160.8	159.8	240.5	278.5	272.1	296.2	319.6	322.4	329.7	334.3	338.4	360.2	385.7	409.4
Concentrates	18.5	18.3	30.9	40.1	42.3	44.8	47.2	48.1	48.8	49.5	50.2	53.6	57.4	61.2
Greens	120.6	125.1	137.2	146.9	135.7	136.7	143.8	139.1	138.1	131.1	134.9	133.1	135.4	135.6
Total DM	299.9	303.2	408.6	465.5	450.1	477.7	510.6	509.6	516.6	514.9	523.5	546.9	578.5	606.2
TDN	155.4	157.1	211.8	242.3	235.0	248.9	265.7	265.3	268.7	267.7	272.3	284.3	300.7	315.0
DCP	14.7	15.0	19.4	22.4	21.9	22.8	24.1	24.0	24.1	23.8	24.3	25.1	26.4	27.5

DM = Dry matter; TDN = Total digestible nutrients; DCP = Digestible crude protein.

concentrates increased from just 18.5 mt in 1970 to 44.8 mt in 2010. By 2030, it is forecasted to be 61.2 mt. The availability of greens improved from 120.6 mt in 1970 to 136.7 mt in 2010, and is forecasted for a modest decrease to 135.6 mt by 2030.

The total available dry matter in the country increased from 299.9 mt in 1970 to 477.7 mt at present. During the last 40 years, the availability of total DM, concentrates, crop residues and greens increased by 59%, 142%, 84% and 13%, respectively. The current availability of TDN and DCP in the country is estimated to be 248.9 mt and 22.8 mt, respectively, and it is forecasted that their availability will be 315.0 mt and 27.5 mt, respectively, by 2030.

Timely forecasting of national animal feed resources is very important for planners and policy makers, as the actual assessment based on the crop production data for any given year is available only after a lapse of 10 to 14 months. Better forecasting provides the right information at right time. In a report, Ramachandra et al. (2007) assessed the feed availability retrospectively though such information will be of limited practical utility. Current and prospective information on feed resources availability is more important for contingency planning. Additionally, the feed resources are more affected by seasonality and other factors such as difficulty in handling and storing crop residues, pest infestation, molding and fire risk (Hilmersen et al., 1984; Owen and Aboud, 1988). The combination of seasonality and storage problems creates an annual cycle of brief peaks in crop residue availability, followed by periods of scarcity. Hence, forecasting of feed resources availability is essential for a country like India to plan properly for exigencies like severe shortage of feed resources.

Ramachandra et al. (2007) projected the availability of dry fodder, concentrates and green fodder at 417, 44 and 138 mt, respectively, by 2020. However, the methodology adopted for this projection is not clear with respect to data set and models used. In the present study, the corresponding figures for the availability of dry fodder, concentrates and green fodder are 360.2, 53.6 and 133.1 mt, respectively. The higher estimates for green fodder in this study are due to the inclusion of the contribution from sugarcane tops and also, the fodder crops. The estimates in this study are better, as

they are worked out based on auto-regressive models, using climatic and non-climatic variables.

Limitation

This study estimated the feed resources availability based on residue to product ratios. A single conversion factor was used for each crop, which does not account for the varietal differences within the crop. Data on variety-specific conversion ratios and variety-wise acreage under each crop are not available. Similarly, the burning of rice and wheat straws in North India is not quantified and to that extent, the quantities of dry fodder availability from these two crops are overestimated. Precise data on amount straw diverted towards the packaging industry is not available and hence, that shortfall is not accounted for. The quantity of grains, especially maize, diverted towards the ethanol industry is also not considered due to non-availability of authentic data. Data in respect of unconventional feed resources such as *Madhuca longifolia* (mahua) cake, *Pongamia pinnata* (karanj) cake, kitchen waste etc. is not available, and hence, not included in the estimation of feed resources. To that extent, feed resources availability is underestimated.

CONCLUSION

The availability of crop residues, greens and concentrate in India for the next 20 years was forecasted by using auto-regressive models, based on 40 years of historical data on crop production and land use patterns. Use of climatic and non-climatic variables in the models resulted in an improved estimation of feed resources. Forecasting of feed resources is essential to ensure better preparedness for dealing with shortage of livestock feeds caused by abnormal weather events. By analyzing the impact of previous climatic and non-climatic aberrations on the feed resources, future or near-term scenarios of availability can be forecasted. They help the decision makers to implement adaptation strategies to ensure sustainable livestock production. These models can also be used for forecasting the agricultural production in the country.

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