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Mixed Silage of Sugarcane Tops for Improving Fodder and Nutrition Availability in Livestock and its Potential Application in Drought-Prone Areas of Maharashtra, India

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Abstract

Due to climate change, the increased frequency and severity of droughts pose a substantial danger to the viability of livestock-dependent small farmers in arid and semi-arid regions. Poor livestock productivity, caused mainly by the alarming feed and fodder crisis, is a significant cause for concern in livestock-dependent farmers. It is essential to address the issues of inadequate fodder availability, high fodder costs during summer/scarcity times, the increasing necessity of fodder camps, and low productivity in animals due to poor nutritional management to improve the livelihoods of resource-poor farmers in rain-fed areas. Maps of drought severity distribution in different tehsils of Maharashtra state and associated annual rainfall during the year 2018 [1] livestock density in different districts, and availability of sugarcane tops (STs) in those areas have been prepared. The performance of mixed silage of STs with fodder jowar in different proportions viz, 25, 50, 75, and 100% in lactating buffaloes was evaluated. Based on the physical evaluation and feeding trial in lactating buffaloes, it was found that mixed silage of sugarcane tops up to 50% level may be used for sustaining milk production in lactating animals during scarcity periods. Based on the availability of STs in different districts particularly the scarcity zones of Maharashtra, the feasibility of utilizing mixed silage of sugarcane tops to improve nutrition and fodder availability during the scarcity period was assessed. In the present study, an attempt has been made to assess the livestock production perspective of the drought situation of the scarcity zone of Maharashtra concerning annual rainfall, livestock density, fodder demand, sugarcane tops availability, and nutritional status of livestock in the cattle camp. The findings of our study suggest that promoting mixed silage practice using sugarcane tops would be a better option for mitigating fodder crisis and nutritional stress during drought/scarcity periods, ensuring the climate-smart and efficient utilization of available resources.

Keywords: Drought; Fodder; Nutrition; Maharashtra; Mixed silage; Scarcity; Sugarcane tops

Introduction

According to IPCC projections, the frequency of droughts is expected to increase over the coming years. In the last decade (2011-2020), the scarcity zone of Maharashtra experienced three droughts, forcing almost 2.5 million animals to relocate to government-supported cattle camps. Farmers in drought-prone areas of Maharashtra are usually small land holder, resource-poor, and mainly dependent on livestock. They are vulnerable to frequent fodder shortages, causing low animal production and productivity [2]. In drought-affected regions, crop yield is significantly affected. The bulk of rural populations impacted by drought rely on livestock for survival. The interventions engaging local farmers should be based on a proper assessment of the field conditions, including the drought declaration, as well as on strong long-term contingency planning for improving the availability of water and fodder, and timely interventions. In addition to other resource-saving initiatives, the government establishes fodder camps to sustain the livestock wealth of resource-poor farmers. In such camps, farmers live alongside their cattle.

In Maharashtra, the area under fodder crops accounts for only 3.06% of the total cultivated area. The state has a dry fodder shortage of 31.3% and a green fodder shortage of 59.4% [3]. The overall availability of fodder and feed resources is not sufficient to cater to the requirements of the prevailing livestock population. In sugarcane-growing tropical countries, sugarcane

tops (STs) are generally used within the economic distance of the sugarcane fields for various purposes such as feeding livestock, roof thatching, industrial boilers for heat generation, etc. Sugarcane fields are mainly situated near assured water sources, i.e., rivers, canals, and wells. Sugarcane tops are about 15 to 25% of the aerial part of the plant consisting of green leaves, bundle sheath, and variable amounts of immature cane [4]. These are fed to the livestock when fresh, dried, or ensiled. The green tops are used as livestock feed during harvesting (October to May) which coincides with the dry season [5]. Without suitable utilization, major parts are left as such or burnt in the field. The seasonal harvesting of accumulated sugarcane tops waste increases environmental pollution and greenhouse gas emissions [6]. Their nutritive value is highly variable and depends on management practices, stalk cutting point, plant maturity, and the number of dry leaves [7,8]. The amount of aerial biomass contributing to sugarcane tops depends on the cultivar type, growing conditions, and management practices. Commercial sugarcane yields 23.3 to 37.0t dry matter (DM) ha^{-1} $year^{-1}$ of structural carbohydrates (lignocellulose) and nonstructural carbohydrates combined [9]. In 2019, world sugarcane production was about 1.95 billion metric t, resulting in approximately 292-487 million t of tops (DM) (FAOSTAT). It was estimated that 15% of STs were used for animal feeding [4]. However, no latest estimates were available.

Animals can meet their maintenance energy needs by consuming STs as the sole ingredient of their rations. Animals either lose condition, barely maintain themselves, or at best, have very low production levels [10]. Livestock requires a balanced diet with high-quality forages to meet their nutritional requirements for maintenance and production. This fact makes the use of STs as sole feeding less desirable because of their low nutrient content, which can reduce livestock productivity. Thus, efforts are required to foster a more effective utilization of available resources and to avoid the generation of potential pollutants, which could contribute to cleaner, greener, and more sustainable livestock production.

In the present study, attempts were made to study the tehsil/district level drought situation in Maharashtra along with livestock population density, cattle camps occurrence, fodder requirements, STs availability, and evaluation of mixed silage of STs in lactating animals. We propose a feasible option for improving fodder availability vis-a-vis nutrition using mixed silage of sugarcane tops for sustaining livestock production during drought/scarcity periods in Maharashtra.

Material and Methods

Study area

In India, Maharashtra state represents the typical tropical drought-prone area growing sugarcane and jowar crops, therefore was selected for the present study.

Rainfall and severity of the 2018-19 drought

The study was focused particularly on the severest drought period that occurred during 2018-19 in Maharashtra. The said drought occurred due to deficit rainfall during the 2018 monsoon season. Information about drought declared tehsils of Maharashtra as per its severity during 2018-19 was collected from public databases [1]. Additionally, the entire state's actual tehsil-wise rainfall during 2018 was collected from the India Meteorological Department database. This collected information was used to prepare the tehsil-level geospatial maps of drought-affected regions of Maharashtra as per their severity (severe, medium, and nil) and the corresponding rainfall status map at the tehsil level. The rainfall during the period was divided into three categories low (<750mm), medium (750-1150mm), and high (>1150mm). Comparative analysis of rainfall and severity of the drought was carried out by studying the correlation between the level of rainfall and severity of drought.

Drought proneness of scarcity zone/rainfed areas of Maharashtra

Information was collected about the geospatial drought frequency-based classification of districts in India with a focus on Maharashtra and rainfall zones of districts of Maharashtra from the available literature.

Status of cattle camps

Cattle camp history since its initiation (Number, location, animals accommodated, etc.) for Maharashtra was obtained from the Animal Husbandry Department, Government of Maharashtra and other open-access databases. Information was collected about the number of districts having cattle camps, the number of camps, and the animals accommodated in the camps during different drought years. Information was collected about feed and fodder arrangements during camp.

Livestock population density and cattle camp requirement during drought

Livestock population data as per the 20th livestock census (2019) was considered for developing tehsil-level livestock population density (Number/km^2) maps. Its association was compared with the severity of drought, rainfall, and the requirement of cattle camps.

Fodder demand and sugarcane tops availability

Information about total fodder demand in Maharashtra was estimated based on livestock population as per the method described earlier [11], and STs availability based on data on sugarcane production [12] and average top availability estimates [13]. District-wise availability of STs was calculated for Maharashtra state for the severest drought year (2018-19) considering tops contributing 15% of total sugarcane production

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for the districts of Maharashtra state. Availability of STs used either as green fodder (during Oct-Mar) or as mixed silage with 50% composition (across the year), for livestock population across all districts of Maharashtra was estimated. The districts were further classified as having high (50-70%), Moderate (30-50%), low (10-20% and poor (<10%) STs availability and presented in the form of a geospatial map.

Preparation and evaluation of mixed silage

Bag silage with STs and its various combinations with fodder Jowar (Phule Suchitra, V1- rabi sorghum) was prepared during October/November. Its performance was evaluated in lactating buffaloes during April/May month. Silage was prepared manually at the livestock research facility of the institute. Cane tops and jowar fodder were chopped separately to an average of 2cm size using a chaff cutter. No additives were used except commercially available silage culture (KVK, Baramati) at 100ml/lit of distilled water for one bag (1tonne) of the total fresh material. Five types of sugarcane tops (ST) silage with Jowar fodder, 25, 50, 75, and 100% ST and 100% Jowar were prepared. The chaffed material was filled by pressing manually to remove the air as far as possible into one-ton capacity silo bags lined by polypropylene bags. The details of the silage prepared along with dry matter content (DM) are given in Table 1. The silage was kept for three to five months before the trial started.

Table 1: Dry matter (DM) of various combinations of silage treatments of sugarcane tops with fodder Jowar.

Treatment	Details	Dry Matter (DM) %
T0	Sorghum (100)	25.75
T1	Sugarcane tops + Sorghum (25:75)	25.83
T2	Sugarcane tops + Sorghum (50:50)	32.8
T3	Sugarcane tops + Sorghum (75:25)	31.16
T4	Sugarcane tops (100)	27.35

Feeding trial

The experiment was conducted in four mid-lactating Murrah buffaloes in April and May. All five types of STs silage with Jowar fodder were fed to four buffaloes in separate pens, using a cross-over design by keeping a seven-day gap in each treatment. The animals were fed ad libitum a 66:34 forage: concentrate diet (DM basis), which consisted of 36% dry fodder, 30% mixed silage, and 34% concentrate mixture. Silage quality assessment was done based on physical characteristics and rating as per the scale (1-4) used as indices, as described earlier [14]. All data related to silage characteristics, nutritional analysis, feed intake, and milk production parameters were recorded. The lactation performance data were analyzed by paired t-test [15].

Results and Discussion

Drought (2018-19) and rainfall (2018) in Maharashtra

During 2018-19, as a consequence of below average (-13%) rainfall (1000.8mm) received during the rainy season (2018), the Government of Maharashtra declared drought in 268 revenue circles based on indicators like rainfall deficit, reservoir storage, groundwater index, and soil moisture. The deficit rainfall situation during the Kharif season affected 151 tehsils in 26 districts, comprising 112 tehsils that reeled under severe drought and 39 tehsils that experienced medium Drought (Figure 1). Most of these areas received <750mm rainfall (75%) or rainfall between 750-1150mm (18%) (Figure 2). Drought was also declared in a few areas (7%) with higher than 1150mm of rainfall. Therefore, there is a need to strengthen drought-proofing mechanisms in areas receiving >750mm of rainfall, besides adapting measures to combat drought.

Drought proneness of Scarcity zone/Rainfed areas of Maharashtra

The information about district-level agricultural drought frequency during 2000-2019 in India, as shown in Figure 3, was obtained from the Mahalanobis National Crop Forecast Centre of the Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India. The rain shadow area of Maharashtra compromises the eastern part of Western Maharashtra and the eastern part of Marathwada, which is mainly the eastern slope of the Western Ghats (Sahyadri Mountains). This includes 14 districts with high drought frequencies, viz. Sangli, Satara, Pune, Ahmednagar, Nashik, Jalagaon, Dhule, Solapur, Osmanabad, Latur, Beed, Aurangabad, Jalana, and Buldhana. These mostly coincide with Maharashtra's deficit (DPAP) rainfall zone [16] (Figure 4).

Though suitable for administrative purposes, the information gained from such types of maps does not depict the ground situation about the possible severity and impact of drought on prevailing livestock. The actual drought situation at ground level is quite different, due to presence of water reservoirs, irrigation facilities, geographical terrain and human interventions. Nowadays, with the availability of GIS-based techniques, A.I. tools and communication systems, new information systems providing real-time geospatial drought situations for field workers are required for the effective implementation of preventive as well as relief measures to reduce human suffering in drought-prone areas.

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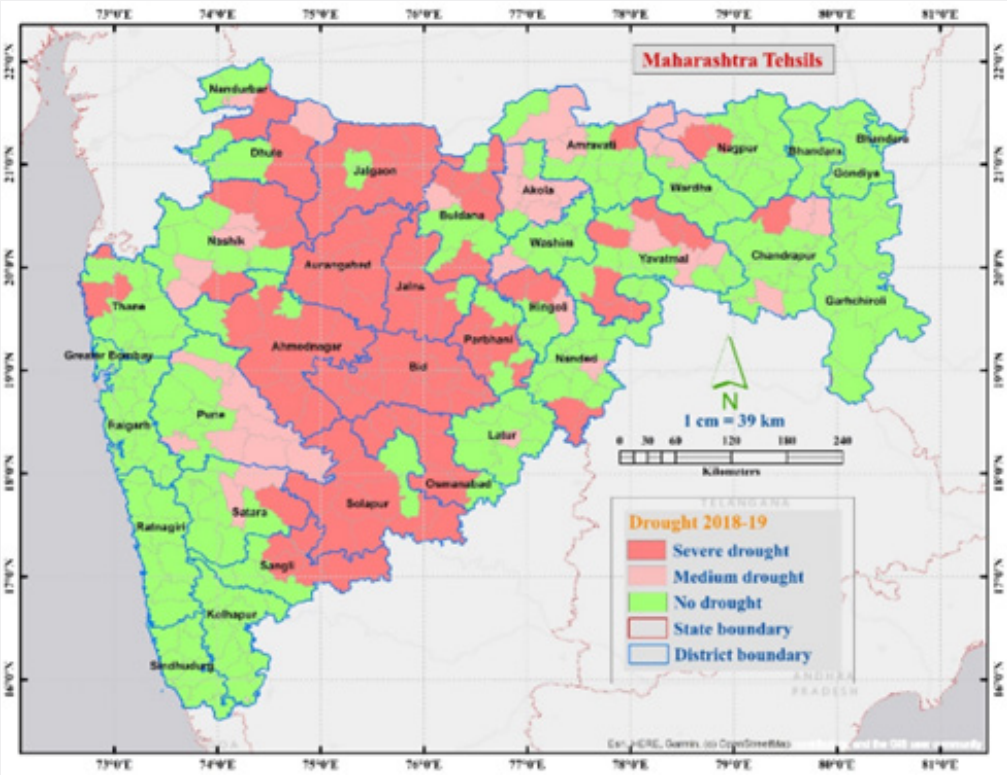

Figure 1: Drought severity in tehsils of Maharashtra in 2018-19.

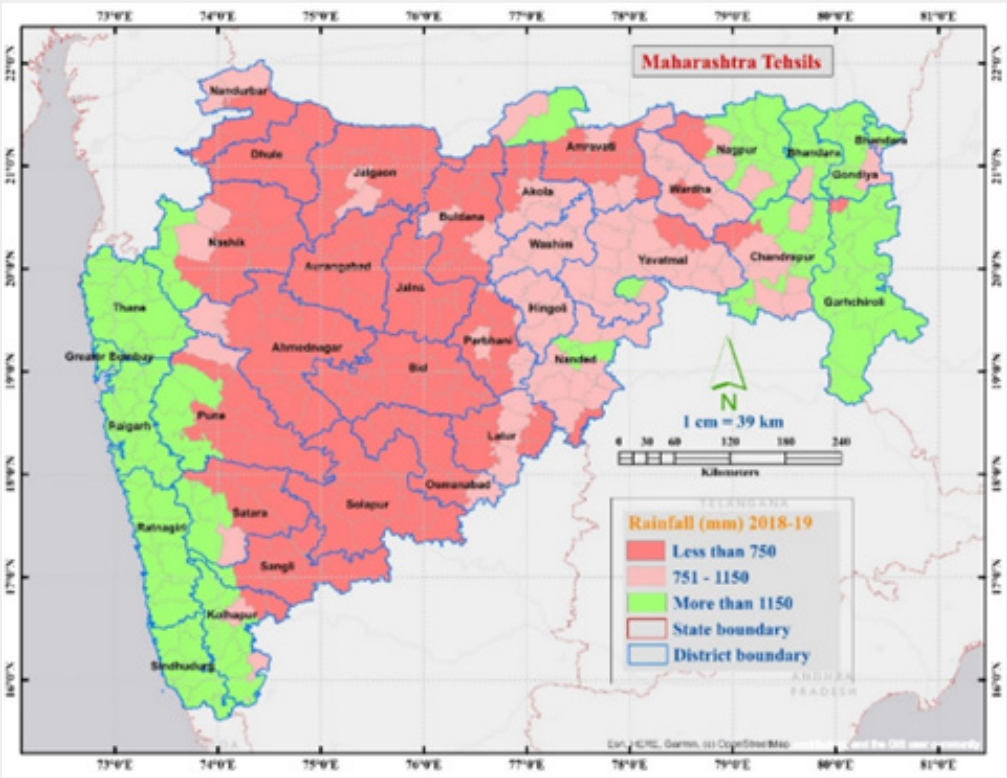

Figure 2: Annual rainfall in 2018 in tehsils of Maharashtra.

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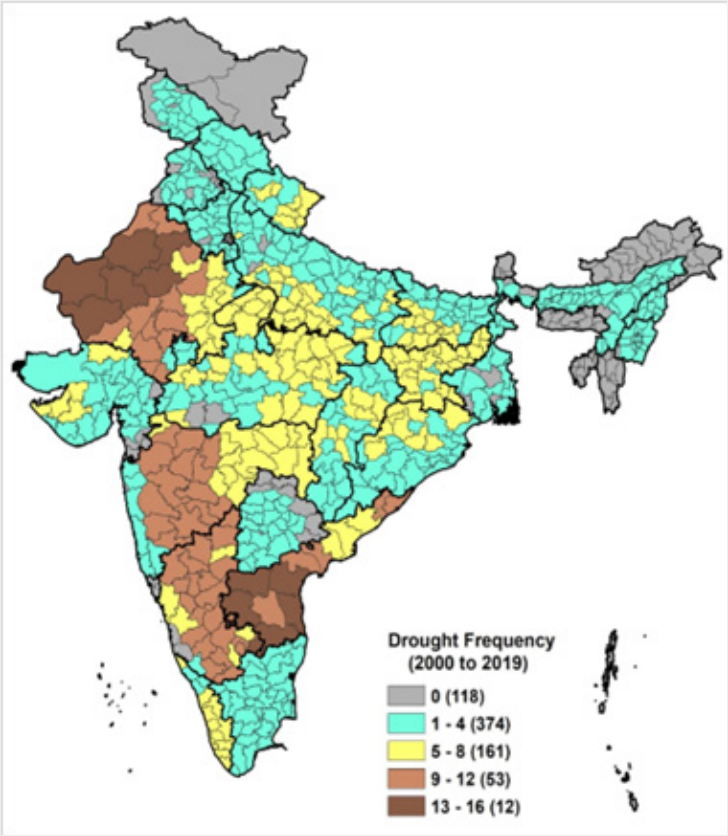

Figure 3: District-level agricultural drought frequency during 2000-2019 in India (Source: MNCFC, DAC & FW, New Delhi).

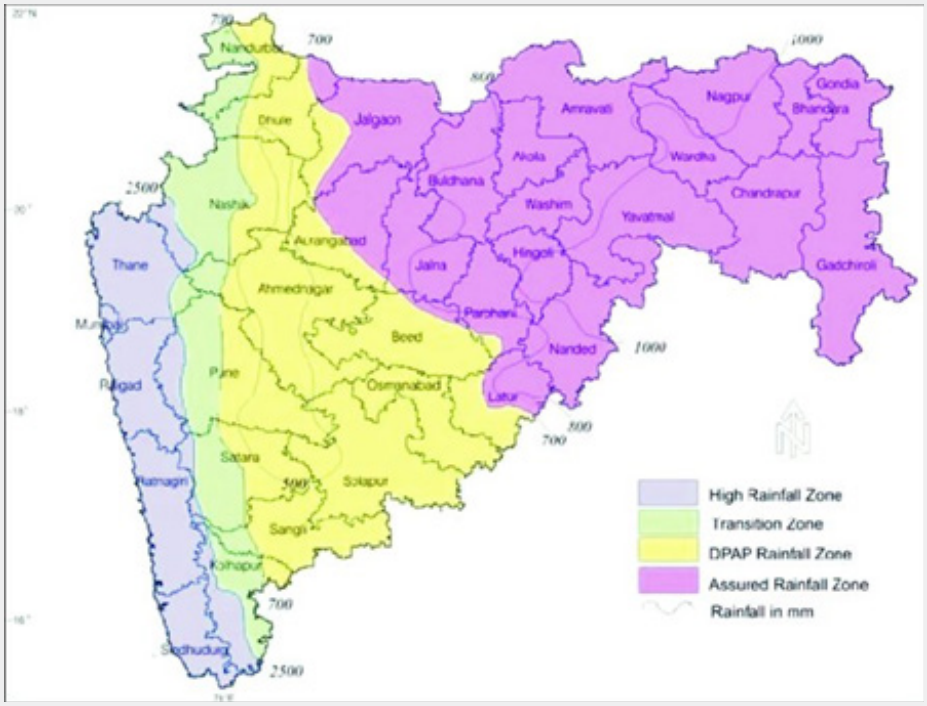

Figure 4: Rainfall distribution of Maharashtra (Source: Maggirwar and Umrikar, 2020).

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Livestock population density and cattle camp history

Tehsil level livestock density (number/km^2) map of Maharashtra was prepared using livestock census data 2019. Livestock density was inversely related to the annual rainfall in that area showing more livestock population in low rainfall areas (Figure 4 & 5) emphasizing the importance of animal husbandry in the areas where agriculture is affected due to low rainfall. There is comparatively less reliance on livestock in the high rainfall areas in Konkan and Vidarbha. However, the sustenance of farmers from drought areas and drought-prone areas depends on livestock. This finding suggests the need to emphasize fodder production and nutrition of the livestock besides the use of stress-resilient animal species and breeds in these areas. The mechanism of early detection of drought and planning for increasing the availability of the required quantity of feed and fodder must be considered a priority. During the widespread scarcity of fodder as a relief measure, the Government of Maharashtra permits fodder camps in drought-affected areas. The information about cattle camps established during drought years since its inception as per Government of Maharashtra records is compiled in Table 2.

Table 2: Cattle camps during different drought years in districts of Maharashtra.

Drought Year	No. of Districts in Which Camps Opened	Total No. of Livestock Camps	No. of Livestock
2018-19	14	1646	11,15,975
2014-15	6	421	4,34,665
2012-13	11	1327	9,80,818
2003-04	6	812	7,02,216
1994-95	5	732	5,42,632
1988-89	4	415	387411
1983-84	2	327	210217
1978-79	Information not available		
1972-73	Information not available		

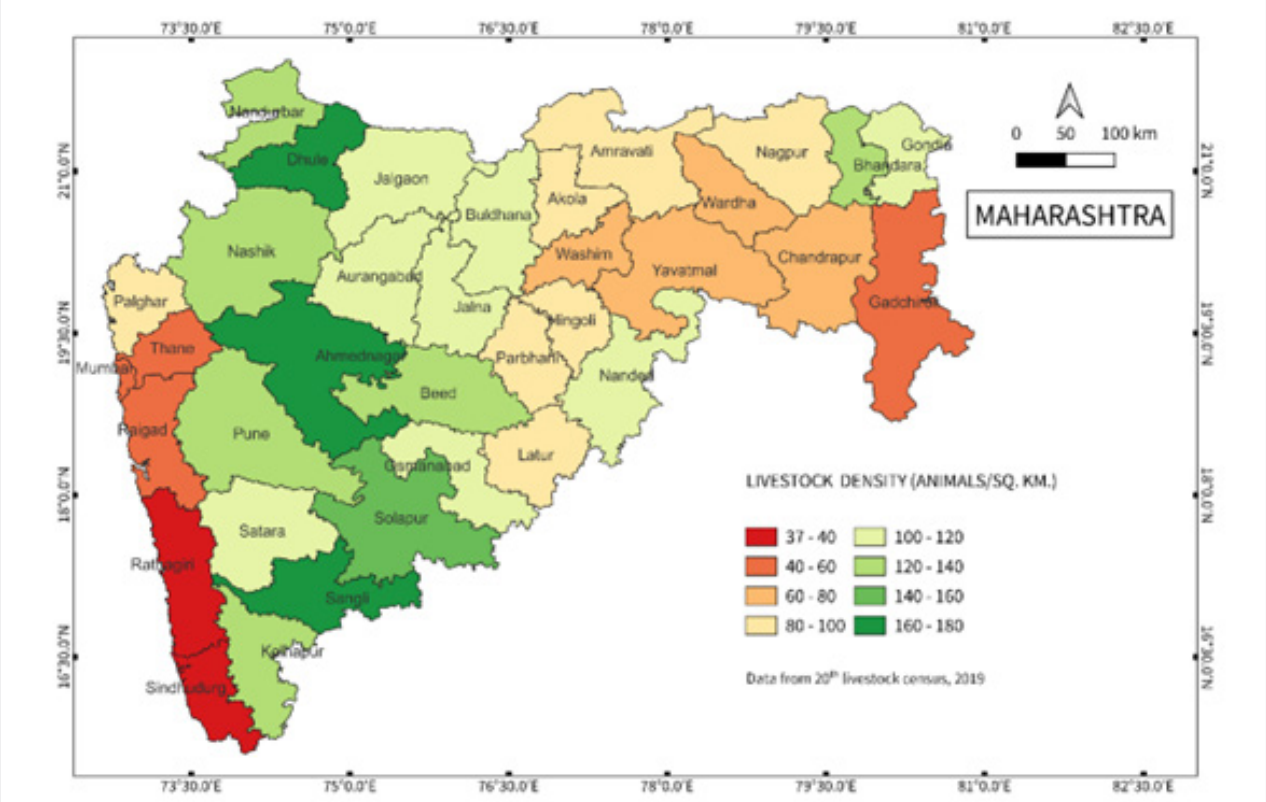

Figure 5: Livestock density (Animals/Km^2.) in districts of Maharashtra as per livestock Census 2019.

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During 2018-2019, 1,646 cattle camps were opened to provide animals with essential fodder, water and medicine, and 11.16 lakh animals were hosted. The drought-affected areas' livestock population was 96.02 lakh large animals and 37.28 lakh small animals. The Maharashtra government made available Rs 4909.50 crore for drought relief in 2018-19, as per the state Economic Survey, adding that the total affected area was 85.76 lakh hectares spread over 151 tehsils. During 2018-19 funds of Rs 35 crore were made available for the production of fodder for animals affected due to drought. A subsidy of Rs. 4,600 ha^{-1} and 25,099 quintal seeds were distributed for the production of fodder among farmers. The total area brought under cultivation was 58,821 ha, and 29.4 lakh Mt green fodder was produced. Though attempts are made to provide balanced nutrition during camp, animals are often fed on chaffed whole sugarcane as green fodder in the absence of other greens. As a result of the shortage, the fodder costs escalate beyond the reach of resource-poor farmers. The overall nutritional status of animals in drought areas is just sustenance type which is based on available dry crop residues, whole sugarcane as fodder and needs much improvement considering livestock's balanced nutritional requirements. The last decade (2011-2020) recorded three droughts requiring 3394 cattle camps hosting more than 2.5 million animals, suggesting planning for preventive measures.

Evaluation of Mixed silage of STs

The silage was evaluated and rated (Table 3) as described earlier [14]. The silage was as rated excellent (4) if found pleasant and sweet-acidic (very pleasant), light/greenish, yellow/Olive green coloured and loose, soft having firm texture. There was no or minimal mould on the top layer and was having pH <4.2. The silage rated good was similar except slightly brownish and moist. The nutritional analysis of the prepared silage is described in Table 4. Jowar or maize fodders are better fodder options for livestock than sugarcane tops considering their crude Protein (CP), feed intake, digestibility and palatability. STs as sole feed can fulfil the maintenance requirements of cattle but are deficient in true protein and various minerals and have low energy value to maintain production. Nutritional analysis of STs, in comparison to the one compiled earlier [4], is shown in Table 4. This is just comparable to other fodder grasses. Hence, ST are not suitable as sole feeding option as practiced by most of the farmers and its inclusion of more than 20% of DM requirement is not advisable. Comparative milk production during feeding of mixed silage as compared to gap periods is described in Table 5. The milk production during silage feeding was significantly higher ($p < 0.01$) as compared to gap periods. However, considering the lactation curve the increase may not be significant as appearing statistically. This suggests mixed silage feeding may be useful for sustaining milk production.

The silage in the present investigation was prepared without any additives. As reported earlier, revealed that both burnt and green STs could be adequately fermented and preserved as silage without additives like urea and molasses and their combination. The mixed silage, particularly 50% or less STs with Jowar fodder, revealed better acceptance in terms of animal feed intake and preference besides its better nutritional composition. Mixed silage of STs up to 50% may be used for sustaining the production of dairy animals during acute fodder crises during water scarcity periods if prepared well in advance during their availability period, i.e. sugarcane harvesting period (October to March). One alternative measure to optimize livestock production using sugarcane by-products is making silage [17]. As per an earlier report [14], using sulfuric acid individually or simultaneously with urea plus molasses was the effective and safe method for preparing STs silage. Seasonal harvesting leading to the accumulation of STs waste may rapidly increase environmental pollution and greenhouse gas emissions [6] as a major part of it is disposed off by burning. This suggests exploration for better management options for available resources i.e., STs.

Table 3: Physical characteristics, feed intake and acceptability of the silage.

Treatment	pH	Temperature ^0C	Rating score	Feed Intake	Acceptability
T0	4.2	28.3	4 (excellent)	95-100%	+++++
T1	3.9	27.9	4 (excellent)	95-100%	+++++
T2	4.1	27.2	4 (excellent)	95-100%	+++++
T3	4.3	28.6	3 (Good)	90-95%	++++
T4	4.4	27.8	3 (Good)	80-90%	+++

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Table 4: Nutritional analysis of mixed silage samples and other forages used in the trial.

Samples	Crude Protein %	Ether Extract %	Crude Fiber %	Acid Insoluble Ash %	Total Ash %	Calcium %	Phosphorus %
T0	6.95±0.06	2±0.17	29.5±0.7	0.24±0.04	7.15±0.22	3.42±0.14	0.08±0.03
T1	5.3±0.44	1±0.36	32±2.46	0.24±0.03	10.5±0.7	1.63±0.1	0.06±0.02
T2	5.86±0.25	1±0.17	31.5±1.99	0.33±0.05	11.17±1.41	3.24±0.49	0.09±0.02
T3	4.42±0.48	3.61±0.43	30.5±2.67	0.41±0.09	10.73±1.82	2.81±0.26	0.14±0.05
T4	5.1±0.44	2.9±0.18	36.9±3.57	0.42±0.04	6.28±1.8	2.95±0.19	0.14±0.02
Concentrate	19.6±1.64	3±0.17	11±1.31	1±0.39	10.67±2.34	2±0.75	0.18±0.02
Dry Fodder	4.6±0.72	2.4±0.61	29.4±3.34	1.2±0.26	12.4±1.04	3.6±1.11	0.7±0.1
Green fodder	6.65±0.54	2±0.53	42±2.84	4.28±0.39	10.53±1.82	0.07±0.02	0.04±0.02
STs *	4.9±1.0	1.5±0.3	34.0±2.6	-	7.7±1.3	2.8±0.5	1.2±0.2

Values are mean± standard deviation, STs- sugarcane tops, *(Naseeven [4]).

Table 5: Comparative milk production during feeding of mixed silage as compared to gap periods.

Treatment	Average Milk Production (Litre)	
	During Silage Feeding	During Gap Period
T0	4.26	4.04
T1	3.32	3.15
T2	4.98	4.71
T3	4.74	4.7
T4	3.69	3.59
Average	4.198	4.038
SE	0.31	0.3
P value	0.0088*	

*denotes significance at p <0.01.

Fodder scenario and sugarcane tops utility

The total fodder requirement of Maharashtra calculated based on 2019 livestock census data is 1406.55 lakh tonnes of greens and 938.68 lakh tonnes of dry fodder. The area under fodder crops is significantly less (3.06% of the cultivated area). Therefore, the availability of fodder and feed resources is not enough compared to fodder requirements and livestock feeds. The state has a dry fodder shortage of 31.3% and a green fodder shortage of 59.4% [3]. This necessitates reliance on crop residues or alternate fodder sources. Maharashtra recorded 1,320.31 lakh tonnes of sugarcane production in the year 2022. Estimated STs availability may be more than 225 lakh tonnes which needs to be used judiciously without hampering the productivity of animals. Though sugarcane tops are not a better feed option for livestock, feed conversion efficiency was high at 20% and low at 30% STs feeding through total mixed ration in calves [18]. This suggests that even 50% of available ST if used for mixed silage production, may fulfil the 15% requirement of green fodder for livestock. Currently, STs are mostly fed directly to livestock or may be used in lesser proportion for silage preparation. Particularly during water scarcity periods, the immature sugarcane crop is also utilized as livestock fodder. The analysis carried out for the districts of Maharashtra state revealed that STs used either as green fodder (during Oct-Mar) or as mixed silage with 50% composition (across the year), can feed about 50-70% of livestock population across four districts (Kolhapur, Pune, Satara and Solapur); 30-50% in three districts (Sangli, Ahmednagar and Latur), 10-30% in 7 districts and less than 10% in remaining 15 districts producing sugarcane (Figure 6). This provides an insight that silage production and consumption will therefore be largely local, rather than transported across districts. However, bringing more area under cultivation of short-duration fast-growing fodder species during the water availability period either exclusively or by replacing partly the long-duration crops like sugarcane will help reduce green fodder shortage during scarcity period. This strategy would be more beneficial for sugarcane growers rearing livestock, owing to the faster biomass production rates and nutritional quality of fodder crops compared to sugarcane. This grown fodder can also be utilized in mixed silage production. Furthermore, popularizing mechanized shredding/cutting practices of STs and other green fodder for mixed silage preparation either through fixed or mobile

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machines and making arrangements for silage bags/pits can help the timely conversion of all available STs into fodder silage. Mechanized mixed silage making through suitable small farmer groups, thus has the potential to improve the availability of better forage options for sustaining livestock production in addition to generating employment opportunities in the drought-prone areas of tropical regions.

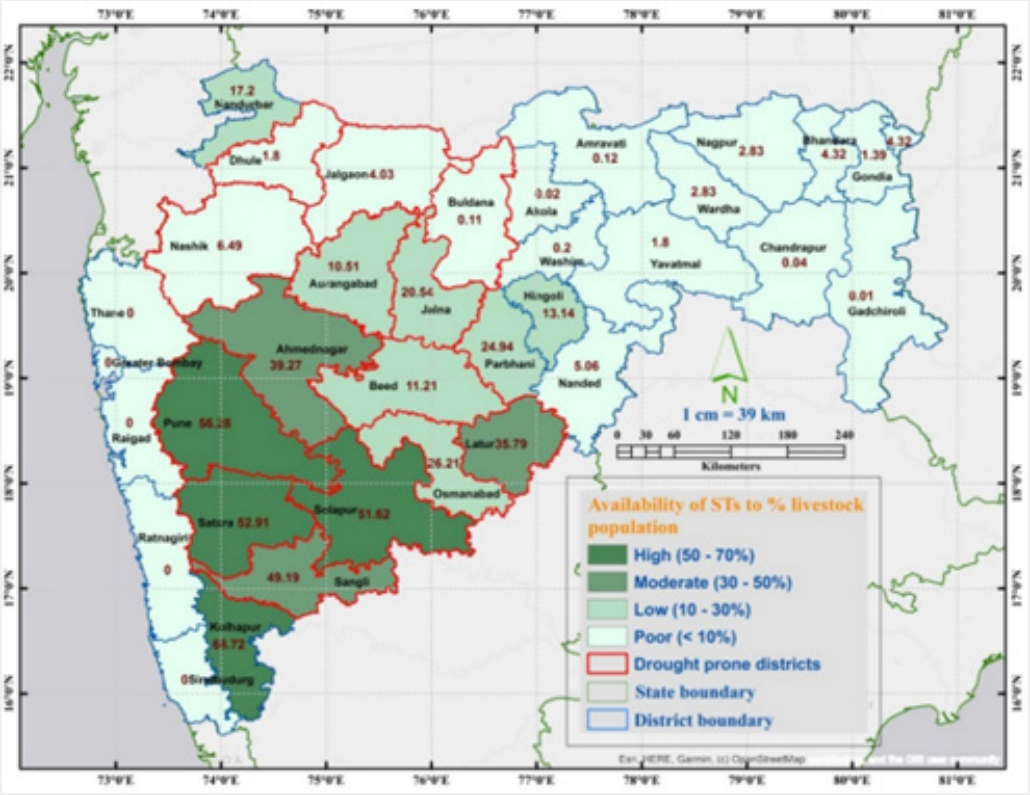

Figure 6: Availability of STs either as green fodder (during Oct-Mar) or mixed silage (across the year) to the percent of livestock in drought prone and other districts of Maharashtra.

At this critical juncture, when climate change-related hardships are threatening the global agricultural sector, particularly in developing nations; besides other adaptation and mitigation measures to reduce farmers suffering, the initiatives to use mixed silage of STs with jowar fodder seem to be an effective way to strengthen efforts to promote and practice sustainable agriculture technologies.

Conclusion

In drought-prone areas, livestock is managed under severe feed and fodder scarcity conditions, and the livestock production system is threatened due to the increasing frequency of drought under climate change scenarios. Providing balanced nutritional requirements to available livestock is a big challenge. It is of prime importance to carefully manage the available resources of sugarcane tops (STs) for livestock feeding particularly to fulfill green fodder requirements. The findings of the present study suggest that mixed silage of STs (up to 50% level) with Jowar fodder resulted in sustaining milk production in lactating buffaloes and if this practice is promoted strategically may help in improving the availability of green fodder and nutrition of livestock in drought prone areas. STs availability (225 lakh tonnes) is higher in most of the drought-prone areas of Maharashtra where the livestock density is also higher. Mixed silage of ST has the potential to fulfill the green fodder requirement of up to 68.72% of the livestock population during scarcity periods and up to 30.65% in drought-prone areas. We may conclude that promoting the practice of mixed silage of STs is a feasible alternative for improving fodder availability and nutrition for livestock in drought-prone areas.

Ethical Statement

The manuscript does not include clinical studies or any invasive procedures. Animals were maintained as per the guidelines of Committee for Control and Supervision of Experiments on Animals (CCSEA). The study was approved by the Institute Research Committee of ICAR-National Institute of Abiotic Stress Management, Baramati, India (CCSEA Registration number: 2190/GO/RBi/SL/22/CPCSEA).

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