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Biophysical characterization of Kangeyam grasslands for land degradation vulnerability analysis

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Abstract

Biophysical resources of Kangeyam grasslands located in Tiruppur district of Tamil Nadu were characterized to identify the vulnerability of grassland soils for land degradation. The grasslands of Kangeyam block were delineated by using high resolution satellite imagery (Resourcesat 2 LISS IV data) which is used as base for resource inventorisation. Soil profile study was carried out to identify the problems and potentials of land resources and surface samples were collected to know the fertility status of grasslands. Very shallow to moderately shallow calcareous red loamy soils were identified in the upper portion and deep calcareous loamy soils were found in lower portion of grasslands. The soil pH of surface soil was ranged from 7.52 to 8.76 and organic carbon ranged from 0.07 to 1.21%. Land degradation vulnerability analysis was carried out by assigning suitable scores to soil parameters, which favours land degradation. Key parameters like surface horizon thickness, pH, OC, CEC and $CaCO_3$ etc. responsible for land degradation were used to identify environmentally sensitive areas for land degradation. The results showed that out of 6 identified soils, two soils (soil B & D) were very highly vulnerable to land degradation and soil C was highly vulnerable to land degradation.

Keywords: Grasslands, Land degradation, Regeneration, Soil indicators, Soil properties

Introduction

The livelihood of a large section of people in India is directly or indirectly depends on the livestock sector. The livestock sector accounts for 25.6% of the agricultural and allied GDP and 4.1% of the total GDP of India (GOI, 2012). The demand for animal origin products is increasing in India due to changing dietary habits of people. To cope up with the increasing demand, there is a necessity to increase the livestock productivity through cost effective measures. Livestock production in India is mainly dependent on grazing and crop residues. More than 50 percent of the fodder requirement of livestock's in India comes from grasslands (GOI, 2007). In addition, grasslands also serve as sources of significant economic products like seeds, tubers, medicinal plants, building materials and gums etc. The total area of permanent pastures and grasslands in India is about 12.4 M ha or 3.9% of the country's geographical area (Roy and Singh, 2013). Grassland system is facing continuous degradation due to natural and anthropogenic factors particularly in arid and semi arid region of the country. Maji *et al*. (2010) reported that out of 12.4 M ha of pastures and grass lands, 2.8 M ha is affected by land degradation. Adoption of inappropriate soil and crop management practices in grasslands exaggerated processes of land degradation resulting in rapid expansion of desertification which is clearly evident by sharp decline in its productivity and species diversity and the quantity and quality of pastures (Suresh *et al*., 2010). Overgrazing (Roy and Singh, 2013), soil erosion (Labrière *et al*., 2015), salinization, nutrient depletion (Hiernaux *et al*., 1999), soil pollution, conversion into croplands and other non agricultural uses are the major causes for grassland degradation in semi arid and arid regions.

Land with better texture, structure, organic carbon and available nutrients in grass lands are less vulnerable to degradation and they are better soil quality indicators for assessing the land degradation in grasslands. Amara and Momoh (2014) recorded soil pH, exchangeable Na and effective CEC as soil quality indicators in soils of Sowa Chiefdom to assess the degradation vulnerability. Pyke *et al*. (2002) developed a qualitative method for rapid assessment of rangelands degradation using 17 indicators in United States. Eswaran and Reich (1998) evaluated land degradation vulnerability based on coefficient of variability of rainfall, depth of soil, extreme levels of chemical and physical conditions and resilience of soil. Hiernaux *et al.* (1999) reported that changes in soil surface features like soil texture, soil structure, bulk density and topsoil organic matter and nutrient contents were good indicators of the health of grazing lands.

Like other grasslands in arid and semi-arid region of India, the Kangeyam grasslands of Tamil Nadu state are also severely affected by land degradation due to severe soil erosion, over grazing, loss of palatable plants, invasion of undesirable plant species, nutrient depletion and improper land management practices (Kumar *et al.*, 2011; Natarajan *et al.*, 2008). Detailed biophysical characterization and assessing the degree of vulnerability of land degradation can help in conserving the degrading grasslands in Kangeyam block. In this context, the present study was carried out to assess the vulnerability of grassland soils by characterizing the grassland resources of Kangeyam block.

Materials and Methods

***Study area*:** Kangeyam block is located in Tiruppur district, Tamil Nadu (Fig.1). The block with a total geographical area of 34072 hectares lies between 77°43'19" to 77°27' 06" East longitudes and 10°54'55" to 11°7'39" North latitudes. The mean annual rainfall of the block is 493 mm and the potential evapo-transpiration is 1684 mm. The mean annual maximum temperature is 33.5°C and means minimum temperature is 25.4°C. Kangeyam grasslands belongs to Agro-ecological sub region 8.3 described as Tamil Nadu uplands and plains, hot moist semi-arid eco sub region with deep red loamy soils, low available water capacity and length of crop growing period (LGP) of 120-150 days.

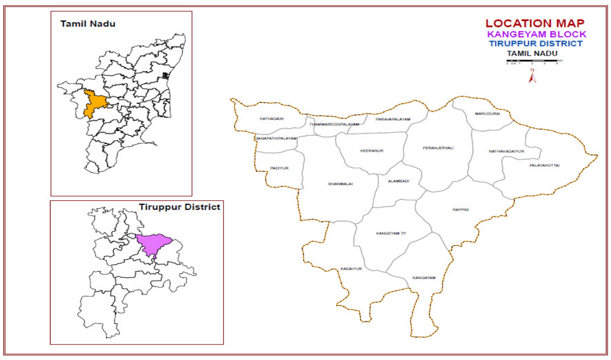

Fig 1. Location map of Kangeyam block

***Land use*:** Kangeyam grasslands are typically grass + legume mixed with annual and perennial trees. The major species in the Kangeyam grasslands are *Commiphora berryi, Acacia leucophloea, Cenchrus ciliaris, Trachys muricata, Seltaria vericulata, Cholris barbata, Indigofera enneaphylla, Crotalaria globosa, Chrysopogon montanus* and *Cynodon dactylon.*

***Data used*:** Indian Remote Sensing (IRS) satellite Resourcesat-2 LISS IV imagery (5.8 m resolution), Tophosheets (58E/12 58E/8, 58 F/9; 1: 50000 scale) are used in the study. Grassland map of Kangeyam was prepared by using *kharif, rabi* and summer season data of 2011-12 LISS IV imagery by visual interpretation based on textural and tonal variations.

***Soil resource inventory*:** Preliminary traverse was carried out by using satellite imageries and Kangeyam grass land maps. Transect analysis was carried out and location of representative profiles were identified based on drainage pattern, surface features, slope characteristics and land use in transects (Natarajan and Sarkar, 2010). In the selected locations, profiles were opened and studied in detail for all their physical and morphological characteristics during April-May 2014. The soil and site characteristics were recorded for all profile sites on standard proforma as per the guidelines given in USDA Soil Survey Manual (Soil Survey Staff, 2003). Profiles were grouped into soils based on identification characteristics. The major differentiating characteristics in the soils of Kangeyam grasslands are soil depth, presence of $CaCO_3$ and soil texture.

***Laboratory analysis*:** Horizon-wise samples were collected for laboratory analysis and 35 surface samples were collected for fertility analysis. Particle size analysis was carried out by international pipette method (Piper, 1966). Organic carbon was estimated by Walkley and Black (1934) method. The soil reaction (1:2.5 soil water suspension), electrical conductivity, cation exchange capacity, exchangeable bases, available macro and micronutrients were determined by standard procedures (Jackson, 1973).

***Land degradation vulnerability analysis*:** Land degradation vulnerability analysis was carried out based on soil physical and chemical parameters by assigning suitable grades for each parameter depending on its impact on land degradation in the grasslands. For each indicator, the range of possible values was grouped into three or four classes using existing classification systems (Natarajan *et al.*, 1997). Sensitivity scores in the range 1–4 were assigned to each class based on importance of the parameter on land degradation. The parameters considered here were soil depth, thickness of surface horizon, surface texture, organic carbon, nutrient status *etc.* To identify the vulnerability of soil

Table 1. Site characteristics of representative soil profiles of Kangeyam grasslands

Soil	Lat &Long	Village	Slope	Erosion	Drainage	Surface fragments
A	11° 6.70"N, 77° 35.3"E	Ganapathipalayam	1-3	Slight	Well drained	<15
B	10° 6.80"N, 77° 30.5"E	Vadasinnapalayam	1-3	Severe	Well drained	<15
C	11° 4.35"N, 77° 29.5"E	Padiyur	0-1	Moderate	Well drained	15-35
D	11° 2.35"N, 77° 35.9"E	Pappini	0-1	Slight	Well drained	15-35
E	11° 6.15"N, 77° 39.5"E	Palaiyakottai	1-3	Moderate	Well drained	<15
F	11° 4.90"N, 77° 32.7"E	Keeranur	0-1	Very slight	Mod. well drained	Nil

Table. 2. Morphological properties of identified soils of Kangeyam grasslands

Horizon	Depth (cm)	Boundary	Colour	Texture	Gravel (%)	Structure	Consistency	Efferve scence
Soil A								
Ap	0-15	cs	Dark brown	sl	20	m1sbk	vf, ns np	ev
Bt1	15-22	cs	Dark brown	sl	20	m1sbk	vf, ns np	ev
Ck	22-100	Weathered $CaCO_3$						
Soil B								
Ap	0-13	cs	Dark reddish brown	sl	10	m1sbk	vf, ns np	-
Bt1	13-32	as	Dark reddish brown	scl	10	m2sbk	f, ss sp	ev
Ck	32-79	Weathered $CaCO_3$						
Soil C								
Ap	0-19	as	Dark brown	sl	30	m1sbk	vf, ns np	-
Bt1	19-35	as	Dark red	scl	40	m2sbk	f, ss sp	-
Ck	35-60	Weathered granite gneiss						
Soil D								
Ap	0-13	cs	Dark brown	sl	10	f1sbk	f, ns np	e
Bw1	13-37	as	Reddish brown	sl	20	m1sbk	f, ns np	es
Bw2	37-62	cs	Dark brown	sl	40	m1sbk	f, ss sp	ev
Ck	62-80	Weathered $CaCO_3$						
Soil E								
Ap	0-22	as	Dark yellowish brown	sl	40	massive	f, ns np	e
Bt1	22-43	cs	Dark reddish brown	sl	20	m1sbk	f, ns np	es
Bt2	43-83	as	Dark brown	scl	50	m1sbk	f, ns np	ev
Ck	83-100	Weathered $CaCO_3$						
Soil F								
Ap	0-20	gs	Dark yellowish brown	scl	-	m2sbk	f, ss sp	ev
Bw1	20-38	as	Dark yellowish brown	scl	-	m2sbk	f, ss sp	ev
Bw2	38-81	cs	Dark brown	cl	-	m2sbk	f, ss sp	ev
Bw3	81-138	-	Dark reddish brown	cl	-	m2sbk	f, ss sp	ev

cs-clear smooth, as-abrupt smooth, gs-gradual smooth, sl-sandy loam, scl-sandy clay loam, cl- clay loam, m1sbk- medium weak sub angular blocky, f1sbk- fine weak sub angular blocky, m 2sbk- medium moderate sub angular blocky, vf, ns np- very friable, non sticky and non plastic, f, ss sp- friable slightly sticky and slightly plastic, f, ns np- friable non sticky and slightly plastic.

towards land degradation, sensitivity scores were assigned to the each parameter. These scores of corresponding soils were divided by the total scores of all parameters.

Results and Discussion

Climate and water resources: Annual rainfall of Kangeyam block is 493 mm with large inter-annual variation. Kangeyam grasslands located on rain shadow region of Western Ghats and receives significant share of the total rainfall from north-east monsoon season (52%). South west monsoon brings about 25% of total rainfall, while summer and winter rainfalls are highly uncertain. Temperature during the north-east monsoon season varies between 29.7 to 31.9° C and 33.5 to 34.8°C during south west monsoon (IMD, 2012). The length of crop growing period (LGP) was assessed to know the duration of moisture availability for pasture growth by FAO model using weekly rainfall, PET and soil available water content. LGP is the duration in days or months when precipitation exceeds 0.5 PET and ends with utilization of stored moisture till it reaches 0.25 PET (Naidu *et al.*, 2012). The length of growing period is 10 weeks which starts from middle of September to the end of November. Groundwater overexploitation in Kangeyam has become significant factor in recent times with sinking of deep borewells, which in some cases reach beyond 1000 feet. From an underexploited block in 2004, Kangeyam block moved onto an overexploited block in 2011 in terms of groundwater use (CGWB, 2009).

Soil Resources: Soil profiles were grouped into 6 soils based on major differentiating characteristics like depth, presence of $CaCO_3$, texture and colour. Site characteristics of representative profiles of identified soils are presented in Table 1. Soil A is very shallow, calcareous red loamy soils occurring very gently sloping uplands whereas soil B is shallow calcareous soils found in very gently sloping uplands and soil C is shallow non calcareous soils. Soil D and E are calcareous moderately shallow and moderately deep soils respectively and Soil E is deep calcareous soils found in lower portion of Kangeyam grasslands. Morphological properties of identified soils are presented in Table 2. The shallow soil depth in soil A, B and C is prabably due to washing out the top soil because of lack of proper soil conservation

Table. 3. Physical and chemical properties of identified soils of Kangeyam grasslands

Depth (cm)	Soil texture (%)			pH	EC (dsm^{-1})	OC (%)	CEC (c mol (p+) kg^{-1}	$CaCO_3$ (%)
	Sand	Silt	Clay					
Soil A								
0-15	73.4	8.6	18.0	8.17	0.44	0.71	11.8	1.50
15-22	65.4	15.4	19.2	8.34	0.20	0.38	14.6	2.00
22-100	Weathered $CaCO_3$							
Soil B								
0-13	70.2	12.2	17.6	8.24	0.14	0.24	14.4	-
13-32	71.6	3.6	24.8	8.30	0.17	0.74	15.7	1.75
32-79	Weathered $CaCO_3$							
Soil C								
0-19	70.1	10.2	19.7	8.23	0.19	0.16	7.0	-
19-35	69.5	7.1	23.4	8.55	0.31	0.37	16.0	-
35-60	Weathered Granite gneiss							
Soil D								
0-13	72.4	8.6	19.0	8.74	0.26	0.39	10.0	0.25
13-37	70.0	17.5	12.5	8.77	0.29	0.39	14.5	3.0
37-62	65.0	19.9	15.1	8.27	0.21	0.32	9.3	3.25
62-80	Weathered $CaCO_3$							
Soil E								
0-22	75.2	9.6	15.4	8.16	0.29	0.32	13.1	1.5
22-43	70.4	11.4	18.2	8.68	0.20	0.29	22.0	2.0
43-83	67.0	8.8	24.2	8.38	0.22	0.13	15.2	2.5
83-100	Weathered $CaCO_3$							
Soil F								
0-20	68.6	6.6	24.8	8.71	1.47	1.30	11.0	3.25
20-38	70.2	6.8	23.0	8.64	2.85	0.62	19.5	4.0
38-81	63.1	7.6	29.2	8.25	2.86	0.90	21.0	4.5
81-138	63.5	8.1	28.4	8.26	3.22	0.03	27.2	3.0

Table 4. Selected properties and nutrient status of surface soils of Kangeyam grasslands

Statistical parameters	pH	EC (dSm^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})
Max	8.76	0.51	1.21	313.60	51.89	940.80	2.06	12.24	16.70	0.56
Min	7.52	0.12	0.07	31.36	7.22	100.80	0.06	0.51	2.90	0.08
Mean	8.26	0.25	0.62	115.79	18.82	367.00	0.65	2.86	7.84	0.27
S.D	0.35	0.09	0.26	52.51	8.77	196.25	0.45	2.29	3.47	0.11
CV	4.25	36.61	41.49	45.35	46.63	53.47	68.62	80.09	44.29	39.04

measures (Natarajan *et al.*, 2010). Less thickness of surface horizon and presence of surface gravels are indicators of loss of top soil due to severe sheet erosion. Except soil D and F which are characterized by a horizon sequence A/Bw, other soils are characterized by A/Bt, suggesting the development of soils. All the soils showed a sub angular blocky structure with slight variation in size and degree of strength due to good base saturation percentage particularly with calcium.

***Soil physio-chemical properties*:** Physio-chemical properties of Kangeyam grassland soils are presented in Table 3. Highest clay content was recorded in Soil F (24.8% in surface and 23 to 29.2% in sub-surface) which is due to lower position of soil profile where deposition of finer material from uplands. Clay content is increasing with depth in all the soils except soil D where clay content is decreasing with depth. The increase of clay content with depth can be attributed to the combined effect of *in-situ* clay formation and eluviations. The soil pH varied from 8.17 to 8.77 and soil D recorded high pH (8.74 in surface and 8.27 to 8.77 in sub surface) followed by soil F. The high pH is attributed to presence of calcic material in the soil (Walia and Rao, 1996). Evans *et al.* (2012) reported that continuous grazing increases the pH over controlled grazing. Electrical conductivity ranged from 0.14 to 3.22 dSm^{-1}. Organic carbon content ranged from 0.16-1.30% in surface and 0.13-0.90% in sub-surface. Highest organic carbon was recorded in soil F due to its position where all the eroded materials were deposited followed by soil A. Lower organic carbon is mainly due erosion, leaching, rapid oxidation and decomposition of organic matter in high temperature (Lalitha and Kumar, 2016). Soil F recorded higher amount of $CaCO_3$ in the control section (3.0 - 4.5%) followed by soil D (3.0-3.25 %). Cation exchange capacity (CEC) varied from 7.0- 14.4 c mol (p+) kg^{-1} in surface soil and 9.3 to 27.2 c mol (p+) kg^{-1} in sub surface.

***Fertility status of Kangeyam grasslands*:** Soil fertility assessment was carried out to know the fertility status of Kangeyam grasslands. Thirty five surface samples were collected from grasslands of Kangeyam block and analyzed for nitrogen, phosphorus and potassium and micronutrients *viz*. Zn, Fe, Mn, and Cu. The soil test results (Table 4) showed that available nitrogen was low (< 280 kg ha^{-1}) in the grasslands of Kangeyam block which ranged from 31.3 to 313.6 kg ha^{-1}. The available phosphorous content ranged from 7.22 to 51.89 kg ha^{-1}. The available potassium content ranged from 100.80 to 940.80 kg ha^{-1}. Overall, Kangeyam grass lands are low in available nitrogen, medium to high in available phosphorous and potassium. Continuous grazing with severe intensity is increasing the amount of P and K in the soil because of livestock faeces. High K content in grassland soils was observed by many researchers due to positive effect of livestock (Naveen *et al.*, 2012).

The DTPA extractable iron content ranged from 0.51 to 12.24 mg kg^{-1} whereas manganese content ranged from 2.9-16.7 mg kg^{-1}. The DTPA extractable copper content ranged from 0.06-2.06 mg kg^{-1} and zinc content ranged from 0.08-0.56 mg kg^{-1}. Except manganese, all other micronutrients are deficient in Kangeyam grassland soils. Low elemental concentration might be due to intensive livestock grazing (Dormaar *et al.*, 1997), severe sheet erosion (Natarajan *et al.*, 2010) and periodical burning of grasslands (Neel *et al.*, 2013).

***Land degradation and vulnerability*:** The major soil indicators of land degradation vulnerability in Kangeyam grasslands are soil depth, surface horizon thickness, surface texture, surface structure, rock fragments, drainage, erosion, pH, organic carbon, $CaCO_3$ content, CEC and nutrient status. The grades assigned to different parameters and the results of vulnerability analysis are presented in Table 5 and 6. The total assigned values of all the parameters for the present study was 35. The vulnerability analysis showed that soil B and D rated as very highly vulnerable to land degradation (0.80) due to fragile soils, low surface horizon thickness, low fertility and organic carbon status followed by soil C which were rated under highly vulnerable (0.78) to land degradation. Soil A and D were rated moderately vulnerable to land degradation (0.69) because of poor organic carbon and nutrient status. Soil F was rated comparatively less vulnerable (medium - 0.54) to land degradation due to its position, deep soil depth and high organic carbon content.

Conclusion

Land degradation vulnerability analysis was carried out by assigning suitable scores to land quality parameters, which favours land degradation. The major soil indicators identified in the Kangeyam grasslands were soil depth, surface horizon thickness, surface texture, surface structure, rock fragments, drainage, erosion, pH, Organic carbon, $CaCO_3$ content, CEC and nutrient status. Soil B and D were rated as very highly vulnerable to land degradation and soil C was rated as highly vulnerable to land degradation. Lands with favourable soil texture, good organic carbon and nutrient status were less vulnerable

Table. 5. Assigning grades to soil parameters for judging land degradation and vulnerability in Kangeyam grasslands

Soil depth (cm)	Thickness of surface horizon (cm)	Surface texture	Surface structure	$CaCO_3$ (%) in control section	pH	Rock fragment (%)	Drainage
<75= (1)	>15 = (1)	scl = (1)	m2sbk, m3sbk = (1)	<2=(1)	7.5-8.5=(1)	<15=(1)	Well drained=(1)
50-75 = (2)	>15= (2)	sl = (2)	m1sbk,f1sbk= (2)	>2=(2)	>8.5= (2)	15-35 =(2)	Moderately well=(2)
<50 = (3)			Massive, f0sbk= (3)				

Erosion	OC % of surface horizon	CEC in control section (c mol (p+) kg^{-1})	Available nutrients (kg/ha)			Status of land degradation
			N	P	K	
very slight= (1)	>1= (1)	>16 = (1)	>560 = (1)	>22 = (1)	>118 = (1)	<0.50 = low
slight =(2)	0.5-1 = (2)	12-16 = (2)	280-560 = (2)	11-22= (2)	118-280 = (2)	0.50-0.60 = medium
moderate =(3)	<0.5 = (3)	<12 = (3)	>280 = (3)	>11 = (3)	280 = (3)	0.60-0.70 = moderate
severe =(4)						0.70-0.80 = high
						>0.80 = very high

Table 6. Assigned grades to soil parameters of different soils for judging land degradation and vulnerability in Kangeyam grasslands

Soils	Soil depth (cm)	Thickness of surface horizon (cm)	Surface texture	Surface structure	$CaCO_3$ in control section (%)	pH	Rock fragments (%)
A	22= (3)	15 = (1)	sl = (2)	m1sbk=(2)	1.75 =(1)	8.17= (1)	0-15=(1)
B	32= (3)	13 = (2)	sl = (2)	m1sbk=(2)	1.85=(1)	8.24= (1)	0-15=(1)
C	35= (3)	19 = (1)	sl = (2)	m1sbk=(2)	Nil = (1)	8.23= (1)	15-35 =(2)
D	62= (2)	13 = (2)	sl = (2)	f1sbk=(2)	2.4 = (2)	8.73= (2)	15-35 =(2)
E	83= (1)	22 = (1)	sl = (2)	massive=(3)	2.0 = (1)	8.16= (1)	0-15=(1)
F	118= (1)	20 = (1)	scl = (1)	m2sbk =(1)	4.9 = (2)	8.71= (2)	nil= (1)

Drainage	Erosion	OC % of surface horizon	CEC in control section (c mol (p+) kg^{-1}	Available nutrients (kg/ha)			Status of land degradation
				N	P	K	
WD= (1)	slight = (2)	0.71= (2)	13.2= (2)	94=(3)	21=(2)	268=(2)	0.69 = moderate
WD= (1)	severe =(4)	0.24= (3)	13.0= (2)	62=(3)	19=(2)	201=(2)	0.80 = very high
WD= (1)	slight = (2)	0.16= (3)	11.5= (3)	62=(3)	21=(2)	224=(2)	0.78 = high
WD= (1)	slight = (2)	0.39= (3)	11.2= (3)	127=(3)	13=(2)	739=(1)	0.80 = very high
WD= (1)	moderate = (3)	0.32= (3)	16.7= (1)	90=(3)	13=(2)	201=(2)	0.69 = moderate
MWD= (2)	v.slight = (1)	1.30= (1)	19.6= (1)	62=(3)	28=(1)	425=(1)	0.52 = medium

to land degradation while those lands with poor organic carbon were highly vulnerable to degradation. The coarse texture and low thickness of the surface horizon showed moderate rate of degradation and vulnerability and these can be good soil quality indicators in the long term along with organic carbon, soil texture and nutrients to assess the land degradation vulnerability in dry areas. Traditional grassland system with appropriate soil and water conservation measures should be promoted to arrest the land degradation and sustain the productivity of grasslands in the long run.

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