Assessment of influence and inter-relationships of soil properties in tropical grasslands of central India

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Abstract: The present experiment was carried out to assess influence and inter-relationships of soil properties in grasslands of three national parks in Madhya Pradesh, Central India. Above ground biomass samples of grass and soil samples were collected during different seasons based on specified measurement protocol by the state forest department. Aboveground biomass of grass showed a characteristic growth pattern throughout the year, increased and achieved maximum biomass at the end of rainy season (September), while started decreasing and attained minimum biomass during pre-summer (March) season. Mean aboveground biomass in the study regions varied from 2.03 (Bandhavgadh National Park) to 5.44 Mg/ha (Kanha National Park) with an average biomass of 3.37 Mg/ha. Biomass showed strong correlation with soil moisture (r=0.69), organic carbon (r=0.77) and electric conductivity (r=0.80) at p=0.05. Correlation between six soil properties showed significant correlation (r=0.90; p=0.01). From this analysis it can be conclude that variation in soil moisture, electric conductivity and organic carbon have direct effect on biophysical properties of grass.

Keywords: grassland, biomass, soil moisture, soil properties, Madhya Pradesh

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1 Introduction

Grasslands are very important biological resources which provide habitat for wildlife, human and their domestic livestock (Parton et al., 1995). About 30 % of the world total soil carbon is stored in the soils of grassland and plays a significant role in global carbon cycle. Tropical grasslands are particularly important, occupy 15 million km^2, and in terms of both area and productivity are nearly equal to tropical forest. Together with temperate grasslands (9 million km^2) they cover about one fifth of the earth's land surface (Leith, 1972; Hall and Scurlock, 1991). Biomass stock varies with regional climate and physico-chemical properties of the soil (Richter and Babbar, 1991). Goroshi et al. (2013) reported more biomass stock in humid regions compared to the arid regions in India. Soil chemical properties can directly affect species composition (Bever, 1994) and major physiological processes of the plants. Soil nutrient availability is vital for understanding impact of above- and belowground trophic interactions for ecosystem functioning (Ettema and Wardle 2002). The strength of above–belowground relations may therefore influence on the availability of nutrients in ecosystems (Haase et al. 2008). Feng et al. (2008) observed the significant positive correlation between aboveground biomass of herbaceous plants and total nitrogen, while significant negative correlation was observed between the biomass and total phosphorous. Singh et al. (2010) observed the significant positive correlation of pH with the availability of nutrients.

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Physical and chemical properties of soil in tropical regions demonstrate considerable spatial variation. The causes of spatial variation in soil properties differ according to scale. Identifying the extent of spatial variability in soil properties is very important for understanding the spatial variability of vegetation. Several studies associated to soil physical and chemical properties revealed that spatial variation of soil in tropical region is directly linked to variation in their geological substrate, soil texture, topography and other factors influencing the development of soil and vegetation. Raghubanshi et al. (1992) reported that, in a tropical dry forest of India, at a finer scale, net nitrogen (N) mineralization rates as well as organic carbon (C) and other soil properties were directly related to slope position. Lugo et al. (1978) at dry forest in Guanica, a subtropical dry forest in Rico observed significant variation in physical and chemical properties of soil. Feng et al. (2008) studied effect of different soil properties on spatial distribution of vegetation at different landscape in dry forest. They observed scrub type forest is situated in the sandy soils, which had a low water holding capacity, while a transition between deciduous and semi-evergreen forest grew on soils with a high content and water holding capacity, respectively.

Several national parks have been established recently in Madhya Pradesh, Central India. The parks are predominantly covered by deciduous forests and grasslands. Number of studies (Goroshi et al., 2010; Parihar et al., 2013; Goroshi et al., 2013) have been carried out in the parks to assess forest biophysical parameters (biomass, leaf area index, phenology) and their interaction with regional climatic parameters and few studies have been carried out to understand these grasslands. The present study aims to understand the influence and inter-relation of different soil properties on the biomass of these grasslands. Consequently, assessing their spatial variability may verify how they influence each other, leading better understanding of role in the major physiological activities of the vegetation.

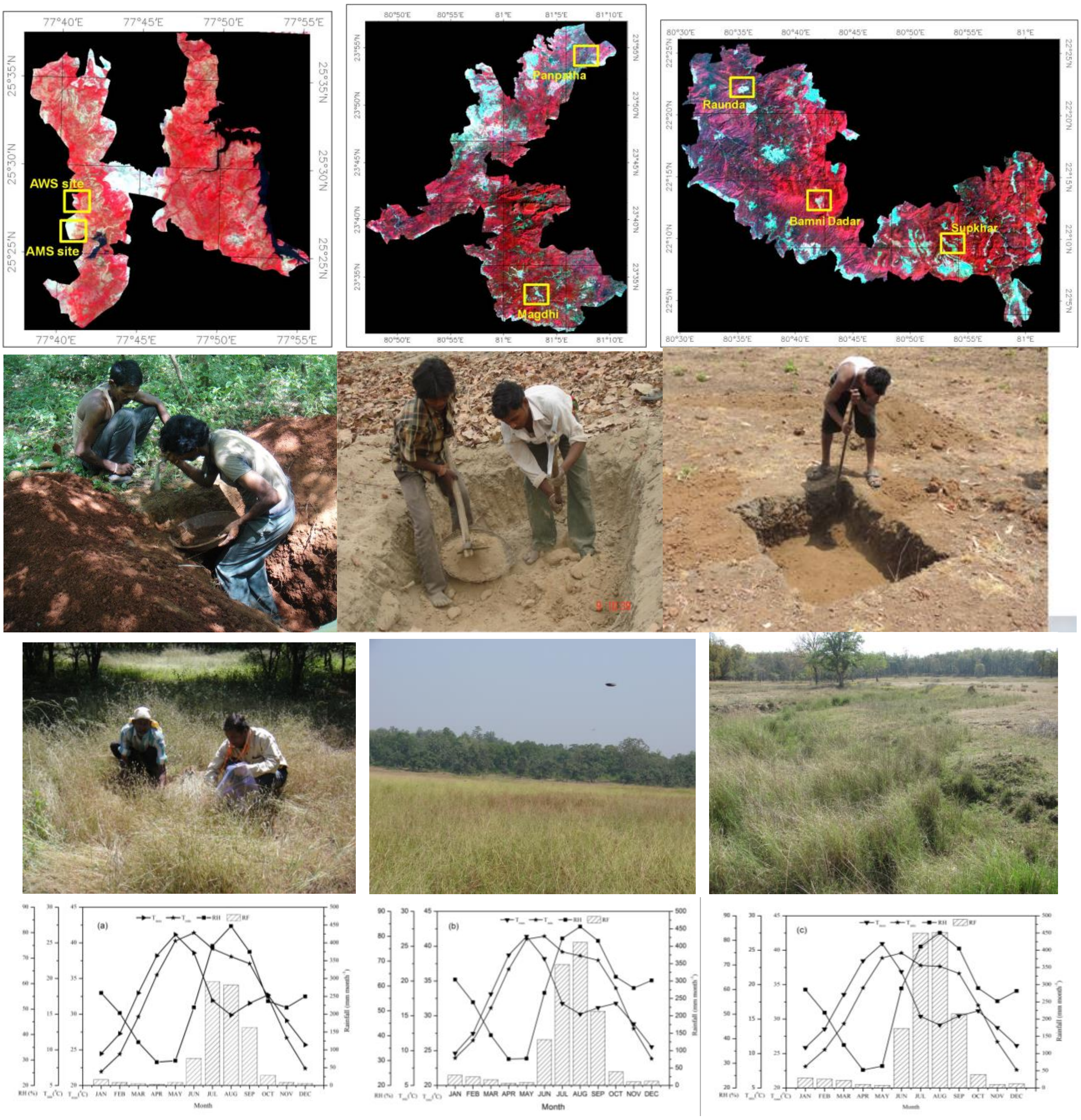
2 Material and methods

2.1 Study area

The study was carried out in grasslands of Madhav National Park (MNP), Bandhavgadh National Park (BNP), and Kanha National Park (KNP) from March, 2010 to March, 2011. Locations of sample plots, soil type, grass type and variability of different meteorological parameters in the study regions are shown in Figure1. Geographic location and grass species in the sample plots are presented in Table 1. MNP is covered by well drained red sandy loam soil with shallow depth hardly exceeding 30 cm above stony concretion. In BNP soil type varies from sandy to sandy-loam. Soil in KNP is finely textured and rich in humus and tends to be somewhat clayey. MNP has relatively sparse vegetation cover with dominance of dry deciduous forest species and shrublands with limited grasslands. In contrast to MNP, BNP has relatively more vegetation with dry deciduous and moist deciduous mixed forest types with limited grasslands. KNP is highly vegetated with moist deciduous forest types and grasslands. Onset of Southwest monsoon in the regions generally occurs in June or early July and continues in to September. About 90 % of the annual rainfall (KNP (1445 mm), BNP (1251 mm) and MNP (896 mm)) in the regions is received in southwest monsoon.

2.2 Data used

Grass biomass and soil moisture (0-30 cm depth) data collected for four months (March 2010, September 2010, December 2010 and March 2011) was used to assess spatio-temporal variability and correlation between them. Due to restriction of soil digging in the park soil samples collected only once in the study period (March 2010) at a depth of 0-15 cm(surface) and 15-30 cm (sub-surface) was used to assess variability of physio-chemical (pH, EC, available N, P_2O_5 and K_2O) properties of soil in the regions. Average value of both depths was used to analyze their correlation with biomass, soil moisture and correlation between different physio-chemical properties of soil.



(a) (b) (c)

Figure 1 Locations of sample plots, soil type, grass type and variability of different meteorological parameters
(a) MNP (b) BNP (c) KNP

Table 1 Geographic location and major grass species in different sample plots

Study area	Site	Geographic locations		Grass species
		Latitude	Longitude	
MNP	AWS (Sailing club)	25°25'13" N	77°12'4.99" E	*Cymbopogon martini, Wats, Cynodon dactylon, Echinocholoa frumentacea, Linn. Eragrostis diarrhena, Eragrostis tenella (Linn) Beauv*
	AMS	25°26'10.1" N	77°41'43.2" E	
BNP	AWS (Magdhi)	22°12'9.4" N	80°41'55.8" E	*Aristida setarea, Saccharum spontaneum, Phragmites karka, Apluda aristata, Cynodon dactylon, Cymbopogon martini* etc
	AMS (Panpatha)	23°54'54" N	81°6'15.6" E	
KNP	AWS (Bamni Dadar)	22°12'9.4" N	80°41'55.8" E	*Alloteropsis cimicina, Andropogon adsariotis, Apluda mutica, Apocopis vaginata, Cyperus compactus, Cyperus iria* etc
	AMS (Ronda)	22°21'43.8" N	80°35'4.5" E	
	Watch tower (Supkhar)	22°11'12.3" N	80°56'26.1" E	

3 Methodology

Space Applications Centre has installed an Automatic Weather Station (AWS) and Agro-Meteorological Station (AMS) tower for micrometeorological studies in grasslands of MNP, BNP, and KNP. Both the stations (AWS and AMS) were installed at MNP, BNP and KNP. By keeping AWS and AMS as a reference point grass and soil samples were collected from all four directions of the tower. Two grass samples from MNP and BNP, while three (AWS, AMS and a watch tower) samples from KNP were collected from 1m × 1m plot. Soil profiles were excavated and samples were collected at 0-30 cm depth for soil moisture analysis. To understand soil physio-chemical properties, soil samples were collected at surface (0-15 cm) and sub-surface (15-30 cm) and then average value at both the depth was used. This sampling was done only once in the study period due to restriction of soil digging in the national park. Fresh weight of grass and soil samples were taken at the sites and the samples were brought to the laboratories at Tropical Forest Research Institute (TFRI) and State Forest Research Institute (SFRI) for analysis. Dry weight of biomass and soil sample was recorded after drying them in hot air oven till the last 2-3 readings were consistent after oven dry. Moisture content was calculated on percent basis. pH and EC of the soil was analyzed by a glass electrode pH meter and Electric conductivity meter. Organic carbon was analyzed using Walkley and Black's rapid titration method Available N, P_2O_5 and K_2O was determined using Kjeldahl method, blue color method and flame photometer. Detailed descriptions of the methods are given in Biswas and Mukherjee (2003). Correlation analysis between biomass and other soil properties was determined using a SPSS 16.0, a statistical software.

4 Results and discussion

Spatio-temporal variability of grass biomass in MNP, BNP, and KNP are shown in Figure 2. A characteristic pattern of biomass was observed in MNP and BNP throughout the year, increased and achieved maximum biomass during rainy season (September), while started decreasing and attained minimum biomass during pre-summer (March) season. Unexpectedly low biomass in rainy season (September) and high biomass in winter season (December) was observed (Figure 2c) in KNP. Average biomass in the study regions are depicted in Figure 3d. Mean biomass in the regions varied from 2.03 Mg/ha in BNP to 5.45 Mg/ha in KNP with an average of 3.37 Mg/ha. Amongst the sites in the regions, biomass was varied from 1.75 Mg/ha (AMS site) to 8.87 Mg/ha (AWS site) in MNP. At BNP it was ranged between 1.84 Mg/ha (Magdhi site) and 2.22 Mg/ha (Panpatha site). For sites in KNP it was varied from 2.5 Mg/ha (Supkhar) to 8.7 Mg/ha (Bamni Dadar). Eventhough BNP situated relatively in humid climatic condition and receives 29% more rainfall than MNP, but biomass was observed low in BNP amongst all the study regions. It could be due to composition of short height grass species in the region. Rapid decrease of biomass after September was due to burning unpalatable grass species like *Imperata cylindrica* and *Saccharum spontaneum*. Unexpected dip at KNP in September might be due to weeding of grasslands as a part of forest management practice in the region.

Vegetation growth in arid and semiarid region is highly dependent on the soil moisture. Correlation between biomass and soil moisture at a depth of 0-30 cm obtained in different months is shown in Figure 3. Significant correlation was observed between both the parameters (r=0.77, p=0.05). It is evident from Figure 3 that when soil moisture was high (September, 2010) in MNP and BNP their biomass was also high. When moisture was low (March, 2010 & 2011, December, 2010) in the regions their biomass was also low in the corresponding months. Considerable increase in the soil moisture in September have strongly influenced vegetative

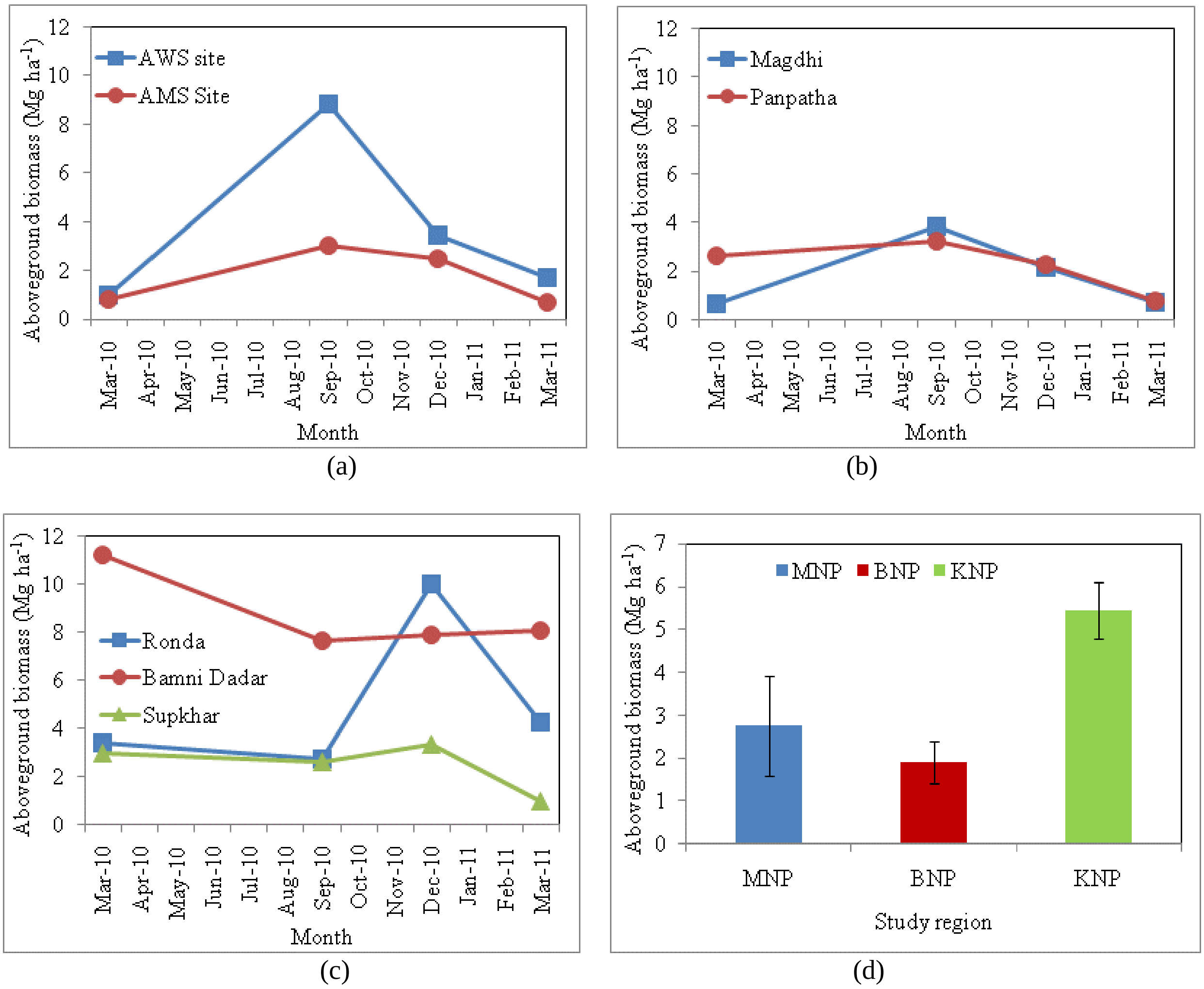


Figure 2 Spatial and seasonal variability of aboveground biomass of grass at different sample plots
(a) MNP (b) BNP (c) KNP (d) Average aboveground biomass of grass at in MNP, BNP and KNP

growth, observed 46% more biomass in MNP and 63% in BNP as compared to their mean biomass. This indicates presence of a strong dependence of grass biomass on soil moisture in dry regions. While no such relation between moisture and biomass was observed in KNP due to frequent rainfall events in the region.

4.1 Spatial variability of soil chemical properties

Physio-chemical properties of surface (0-15 cm) and sub-surface (15-30 cm) soil in MNP, BNP and KNP are presented in Table 2 pH was found relatively higher (alkaline) in both surface and sub-surface soils of MNP, whereas relatively acidic pH range was observed in KNP. Out of all

Table 2 Chemical properties of surface (0-15 cm) and sub-surface (15-30 cm) soils in MNP, BNP and KNP region

	Study site	pH	EC (μs/cm)	Organic carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Madhav National Park	AMS site#	6.68	9.30	0.93	125.44	32.63	207.5
	AMS site¶	6.56	7.60	0.50	94.08	21.31	135.2
	Average	6.62	8.45	0.715	109.76	26.97	171.35
	Sailing club#	7.66	21.9	0.76	203.84	46.57	312.5
	Sailing club¶	7.52	19.1	0.45	146.55	29.25	252.4
	Average	7.59	20.5	0.60	175.195	37.91	282.45
Bandhavgadh National Park	Magdhi#	6.38	13.00	0.86	280.88	32.87	162.50
	Magdhi¶	6.20	8.48	0.28	182.24	22.97	150.00
	Average	6.29	10.74	0.57	231.56	27.92	156.25
	Panpatha#	5.82	7.60	0.39	141.12	15.32	132.50
	Panpatha¶	5.58	2.53	0.09	109.76	13.95	102.00
	Average	5.7	5.06	0.24	125.44	14.635	117.25
Kanha National Park	Ronda#	5.48	21.95	1.48	204.47	29.81	168.75
	Ronda¶	5.26	11.92	0.89	184.24	18.47	110.62
	Average	5.11	6.19	1.58	280.29	14.79	108.96
	Bamni Dadar#	5.15	6.38	2.02	307.68	18.41	122.50
	Bamni Dadar¶	5.08	6.00	1.14	252.90	11.17	95.42
	Average	5.37	16.93	1.185	194.35	24.14	139.68
	Supkhar#	5.66	17.56	2.12	356.25	22.56	178.88
	Supkhar¶	5.51	15.22	2.08	214.00	20.32	174.50
	Average	5.58	16.39	2.1	285.125	21.44	176.69

#Surface soil and ¶Sub-surface soil

the study sites electric conductivity (EC) was found relatively higher in surface soils of MNP (Sailing club) and KNP (Ronda). Organic carbon (%) content was found high in both surface and sub-surface soils of KNP except at sub-surface soils in Ronda site, whereas least organic carbon was observed in surface and sub-surface soils of BNP. The highest available nitrogen (N) was observed in surface and sub-surface soils of KNP, whereas least N content was found in sub-surface soils of MNP (AMS site). Available phosphorous and potassium was found relatively high in the surface soils of MNP (Sailing club), whereas low phosphorous and potassium was observed in sub-surface soils of KNP (Bamni Dadar).

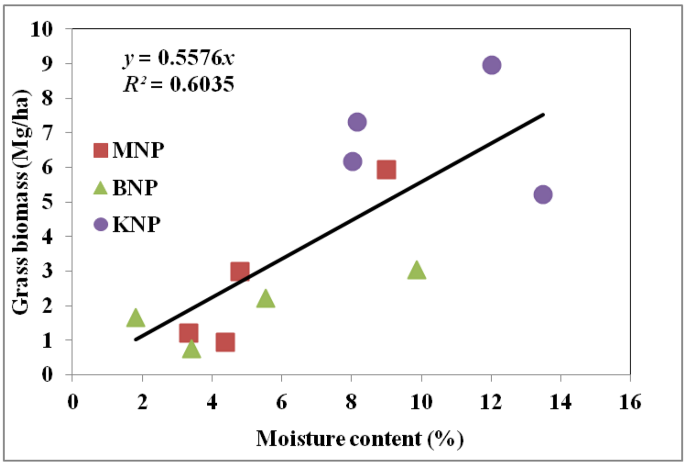


Figure 3 Correlation between biomass and soil moisture (0-30 cm depth) obtained in different months

4.2 Relationship between biomass and soil chemical properties

Correlation analysis was carried out for biomass, soil moisture (0-30 cm) and 6 soil chemical properties which showed intra and inter-relationships between them. Of 28 pairs in correlation matrix, 7 pairs indicated significant positive correlation among them (Table 3). Strong correlation of biomass was observed with SM (r>0.69), EC (r>0.80) and OC (r>0.77) at p<0.05, whereas no correlation or non-significant correlation of biomass was found with pH, P_2O_5 and K_2O. Significant correlation of pH was found with P_2O_5 (r>0.88) and K_2O (r>0.88) at p <0.01. Strong correlation of available N was observed with organic carbon (r>0.79) at p <0.05 and a good correlation of available K_2O was found with P_2O_5 (r>0.9) at p <0.01.

Table 3 Correlation matrix for aboveground biomass of grass and different soil properties (n=56) for assessing influences and inter-relationships

	AGB	SM	pH	EC	OC	N	P_2O_5	K_2O
AGB	1.00							
SM	0.694^{*}	1.00						
pH	-0.233^{ns}	0.054^{ns}	1.00					
EC	0.805^{*}	0.487^{ns}	-0.096^{ns}	1.00				
OC	0.772^{*}	0.257^{ns}	-0.529^{ns}	0.537^{ns}	1.00			
N	0.534^{ns}	-0.072^{ns}	-0.465^{ns}	0.371^{ns}	0.796^{*}	1.00		
P_2O_5	0.018^{ns}	0.039^{ns}	0.884^{**}	0.316^{ns}	-0.283^{ns}	-0.221^{ns}	1.00	
K_2O	0.206^{ns}	0.230^{ns}	0.882^{**}	0.244^{ns}	-0.143^{ns}	-0.147^{ns}	0.902^{**}	1.00

Note: *, ** Indicated relationships significance level at p <0.05 and p<0.01; 'ns' non-significant and '-' sign denoted negatively correlated.

5 Conclusions

An attempt was made to assess the influence and inter-relationship of soil properties on the biomass of grass. Regular observations on biomass and soil moisture at grassland ecosystem in Madhya Pradesh, Central India indicated a good understanding about their interrelations. Consistent observation of biomass in different season showed a peak biomass in September, while least biomass in March. Mean biomass between the study regions varied from 2.03 Mg/ha to 5.44 Mg/ha with an average biomass of 3.37 Mg/ha. The low biomass was observed in Bandhavgadh National Park, which was a moderate rainfall region among all the study regions while the highest biomass was observed in Kanha National Park, a high rainfall region. Correlation between biomass and soil moisture obtained in different months indicated a strong correlation (r=0.77; p=0.05). An analysis of correlation between biomass and soil chemical properties obtained from different sample plots showed significant correlation with SM (r>0.69), EC (r>0.80) and OC (r>0.77) at p<0.05, whereas non-significant correlation was found with pH, P_2O_5 and K_2O. Thus from the present analysis it can be concluded that variation in soil moisture and different soil chemical properties have direct effect on grass biomass in MNP, BNP and KNP.

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