Vol. 42, No. 3, pp 268-275, 2014
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Impact of crop covers on soil properties, runoff, soil-nutrients losses and crop productivity in Vertisols of central India

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ARTICLE INFO

Article history :
Received : July, 2013
Revised : March, 2014
Accepted : April, 2014

Key words :
Crop cover,
Nutrient loss,
Runoff,
SOC,
Soil loss,
Vertisol

ABSTRACT

A field experiment was conducted to evaluate the crop covers for their impact on soil and nutrient losses through runoff and status of soil organic carbon (SOC) and other structural parameters of vertisol. Seven treatments consisted of three sole crop covers *viz*., soybean, maize and pigeon pea and three intercrop covers namely soybean+ maize (1:1), soybean + pigeon pea (2:1) and maize + pigeon pea (1:1) along with one cultivated fallow (control). Results obtained over two years of experimentation revealed that the highest runoff (208 mm) and soil loss (2.87 t ha^{-1}) was recorded higher under cultivated fallow as compared to sole as well as intercrops in both the years. Among the crop cover treatments, the runoff and soil loss was significantly higher under sole pigeon pea (177 mm and 2.15 t ha^{-1}), respectively followed by sole maize (167 mm and 1.99 t ha^{-1}), maize + pigeon pea (140 mm and 1.60 t ha^{-1}), soybean + maize (135 mm and 1.48 t ha^{-1}), soybean + pigeon pea (132 mm and 1.34 t ha^{-1}) intercrops and lowest was under soybean sole crop (132 mm and 1.48 t ha^{-1}). The losses of soil organic carbon (23.55 kg ha^{-1}) and total NPK (5.59, 0.65, 23.91 kg ha^{-1}) were the highest under cultivated fallow over sole and intercrops. The losses of SOC and total NPK were lower under sole soybean and its intercrops as compared to sole crops of maize and pigeon pea. System productivity in term of soybean equivalent yield (SEY) was significantly higher under maize + pigeon pea (5164 kg ha^{-1}) and soybean + maize (3193 kg ha^{-1}) as compared to soybean yield. Therefore, the combinations of maize + pigeon pea (1:1) as an intercrop is the best options in reducing runoff, soil-nutrient losses and sustaining crop productivity of system

1. INTRODUCTION

Water erosion is a serious problem in India. The main factor directly or indirectly responsible for soil and land degradation process is water erosion (Spaan, 2005). It degrades the top productive layer of soil through huge losses of nutrients alongwith runoff and suspended sediments and results in declining productivity of land in the long run. Decline in land quality is attributed to various land degradation processes and amongst them the water induced erosion is single most destructive one (Lal, 2001). Sehgal and Abrol (1994) reported that out of 329 m ha total geographical area in the country, about 57% land (187.7 m ha) is under various forms of degradation in which the dominant form is water erosion (148.9 m ha; 45%). However, according to a latest estimates, the land degradation due to water is reported to the 120.72 m ha area (68.4%) in the country (Maji, 2007). Dhruvanarayana and Ram Babu (1983) estimated that about 5334 m tonnes (16.35 t ha^{-1}) soil is detached annually due to water erosion. The loss of plant nutrients with eroded soil is said to be 8.4 m tonnes including 2.5 m tonnes N, 3.3 m tonnes P and 2.6 m tonnes K in a year. The loss of any amount of soil by erosion is generally not considered beneficial but field experience as well as scientific research has indicated that some soil loss can be tolerated without affecting the crop production significantly (Schertz, 1983). Land restoration strategies are mostly based on a single generalized permissible erosion loss limit of 11.2 Mg ha^{-1} yr^{-1}. This value is considered on the basic assumption that this rate of soil erosion equals to rate of soil formation (Mannering, 1981; McCormack *et al*., 1982). According to soil erosion status report of Chhatisgarh soil erosion is characterized as very slight (<5 Mg ha^{-1} yr^{-1}), slight (5-10 Mg ha^{-1} yr^{-1}), moderate (10 -15 Mg ha^{-1} yr^{-1}), moderately severe (15-20 Mg ha^{-1} yr^{-1}), severe (20-40 Mg ha^{-1} yr^{-1}), very severe (40-80 Mg ha^{-1} yr^{-1}) and extremely severe (>80 Mg ha^{-1} yr^{-1}) erosion, respectively (Tamgadge *et al*., 2003). Soil erosion and land degradation are severe problems in India. Severe surface erosion is linked with intensive rainstorms, high detachability of surface soil materials and reduced infiltration. This is induced by poor and weak soil structure and by poor cover of vegetation or plant residue in critical periods (Pla, 1997). The vegetative covers provided through agronomic measures on soil surface proved effective in conserving the runoff water and decrease the erosivity of rainfall and erodibility of soil (Samra and Sharma, 2002). It was estimated that about 16 and 30 t ha^{-1} soil gets eroded annually at 2% and 3% slope, respectively from cultivated fallow plot in deep alluvial soil in absence of any canopy cover on the soil surface (Narayan and Bhusan, 2000). Vegetation covers protects the soil from intense rain and reduce the detachability of surface materials. It reduces runoff, conserves moisture and retains sediment and organic debris. It also allows drainage of excess water due to their semi-permeable nature (Kiepe, 1995). Different agroforestry systems showed large variations in soil organic carbon (Panwar *et al.,* 2013). Soil erosion affects physical, chemical and biological make up of the soil and thus results in low crop productivity (Bhardwaj and Sindhwal, 1998). The intrinsic soil properties and land use/land cover are important factors which govern sediment production (Wood, 1987). About 73 m ha of land in India is under vertisols spread across Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, Gujarat, Rajasthan and parts of Karnataka, mostly confined to the semi arid region. These soils being rich in clay content when subject to erosive storms under sloppy and undulated topography are characteristically prone to run off and eventually results in greater soil and nutrient losses. By and large, the rate and extent of runoff, soil loss and nutrient losses are primarily influenced by the type of vegetative cover on the soil surface, slope of land and rainfall characteristics (Singh *et al*., 1997). Therefore, in order to sustain productivity of this valuable resource, it becomes necessary to reduce runoff, soil and nutrient losses by water erosion. The maintenance of vegetative cover is of great significance to dissipate the erosive energy of heavy rains. The effectiveness depends upon the percent coverage and height and thickness of the canopy. On arable lands canopy cover can be managed through selection of cropping systems, crop rotations, planting techniques and vegetative barriers (Narain *et al.,* 1994). Khisa *et al*. (2002) observed the lowest soil losses under highest plant cover of intercropping. Jat *et al.* (2008) reported that maize+black gram system was found effective in controlling runoff and soil loss as compared to sole maize. Singh *et al*. (2007) observed that the improved management on soil and water conservation of the vertic Inceptisol decreased surface runoff by 24.27% and soil loss by 44.47% as compared to traditional management.

In the Malwa Plateau region of Central India, soybean, maize and pigeon pea are predominant crops grown during *kharif* season. Being erosion permitting crops like maize, sorghum needs to be grown in combination with legume crops, which helps in quick and thick canopy cover to reduce the soil and nutrient losses. The information on effect of crop covers on runoff, soil and nutrient loss for this region is scanty. Keeping this in view the present study was conducted to evaluate the different combinations of crop covers for runoff, soil and nutrients losses through runoff in Vertisol of central India.

2. MATERIALS AND METHODS

Study Region

A field experiment was conducted at Indian Institute of Soil Science, Research farm, Bhopal Madhya Pradesh ($23^0$18'N longitude, $77^0$24' E latitude and 485 above msl) under 1% slope during season of year 2010 and 2011. The region has a hot sub humid climate with 1200 mm mean annual rainfall and 1400 mm mean annual evapo-transpiration. The soil of the experiment site is a deep Vertisol (Typic Haplustert) with clayey texture (52% clay). Soil have the pH of 7.95, electrical conductivity of 0.21dS m^{-1}, organic carbon 0.52%, bulk density 1.35 Mg m^{-3}, available nitrogen 131 kg ha^{-1}, available phosphorus 13.4 kg ha^{-1}, available potassium 337 kg ha^{-1}, mean weight diameter 0.74mm, field capacity of 38% and permanent wilting point of 24% on volume basis.

Experimental Details

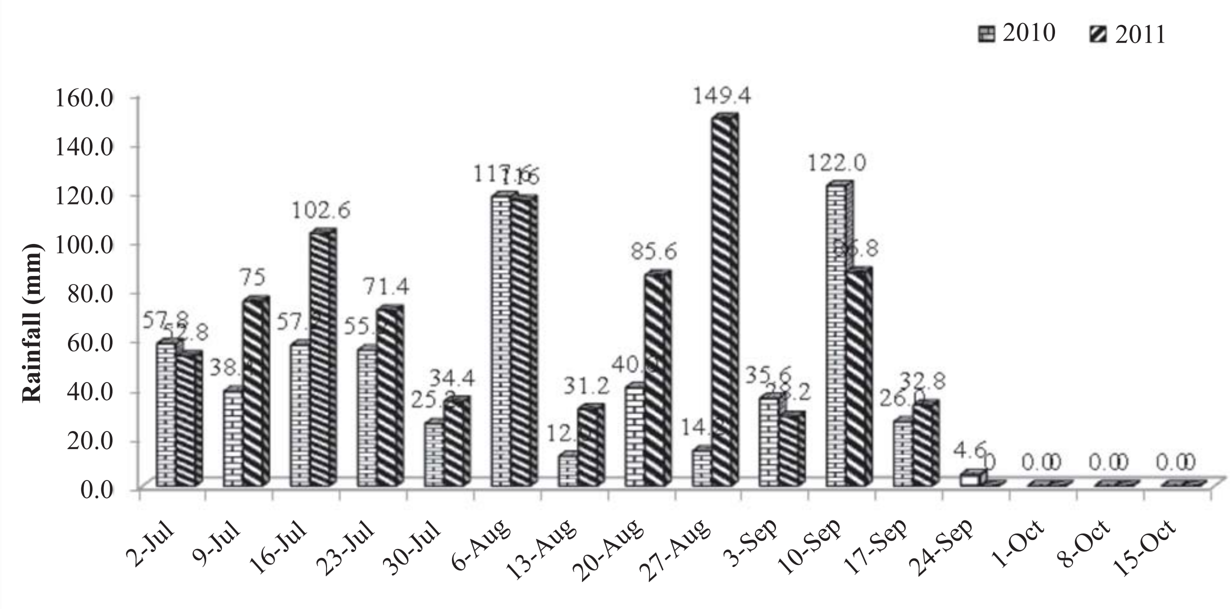
The experiment was conducted in runoff plots having size of 10m x 5m having 1% slope. The runoff and soil loss were measured with help of multi-slot divisors and runoff was collected in cemented tank in each plot. The seven treatments were tested *viz*., T_1: Soybean (sole), T_2: Maize (sole), T_3: Pigeon pea (sole), T_4: Soybean + Maize (1:1), T_5: Soybean + Pigeon pea (2:1), T_6: Maize + Pigeon pea (1:1) and T_7: Cultivated fallow. The treatments were replicated thrice and crop was grown with recommended doses of NPK fertilizer (soybean 30:60:30, maize 120:60:40 and pigeon pea 30:40:30) plus a blanket dose of 5 t FYM ha^{-1}. The row spacing of soybean, maize and pigeon pea were kept 30, 60 and 90 cm, respectively. The crops were sown at optimum soil moisture in the first week of July and harvested in the month of October (soybean and maize) and January (pigeon pea).

Rainfall Distribution

The rainfall data were collected manually from rain gauge installed at the farm. Rainfall received during crop growing seasons was 650 and 866 mm in the year 2010 and 2011, respectively. There were only two runoff events in the year 2010 but 20 such events in the year 2011 occurred at regular intervals during *kharif* season. In the year 2010, the onset of monsoon was late. The rainfall in the months of June, July, August and September was 78.4 mm (10.34%), 206 mm (27.2%), 200 mm (26.4%) and 152.6mm (20.1%), respectively, that contributed 84% of total annual rainfall. The distribution of rainfall during the rainy season was quite good for crop growth. In year 2011, although total annual rainfall received at the experimental farm was 1067.8 mm, but rainfall during crop period was 866 mm only. The rainfall received was 201.6 mm (18.9%), 307.8 mm (28.8%), 320.4mm (30%) and 238mm (22.9%) in June, July, August and September, respectively. In this year the rainfall was uniformly distributed and there was no dry spell during the crop growth period. The week wise rainfall distribution of both years during the crop growth period is given in Fig.1.

Runoff and Soil Analysis

Surface runoff from the each experimental plot was diverted through multi-slot divisor and that from one slot in to the collection tank. The collection system consisted of 350 litre capacity drums installed at the lower end of each plot. After every event of runoff causing rainfall, the depth of the water level in the drum was measured in the morning. Total runoff volume was calculated multiply by 11 slots for per plot and further convert in per hectare basis. A representative runoff sample was collected from each treatment (tank) after thorough mixing. One litre of runoff sample was taken from each tanks and evaporated to dryness to determine weight of the soil sediments. A separate runoff sample was collected from the each tank for estimation of the nutrient losses. The soil samples were collected after end of two years of experiment for determining any changes in the soil properties. Soil physical parameters were measured for bulk density (BD) with undisturbed by core sample method (Black, 1965), mean weight diameter (MWD) using Yoder's apparatus (Kemper and Rosenau, 1986), penetration resistance (PR) by digital cone Penetrometer (Rimik CP 40 II), infiltration rate (IR) using a double ring infiltrometer (Richard, 1954), crack volume (CV) using equations (Dasog and Shashidhara, 1993). The chemical properties of soil like soil pH, soil organic carbon (SOC) and available N, P and K, were analyzed by adopting standard procedures outlined by Jackson (1973). The soybean equivalent yield (SEY) was calculated by converting the cost of maize and pigeon pea to cost of soybean. The soil moisture content was estimated by gravimetric method at sowing and harvest stage of crops.



Week wise rainfall distribution of crop period year 2010 and 2011

Fig. 1. Rainfall distribution during crop period in year 2010 and 2011

Statistical Analysis

The differences between treatments tested based on analysis of variance (ANOVA) procedure (Gomez and Gomez, 1984). Superior treatments were identified based on a comparison of treatments pairs using Least Significant Difference (LSD) at $p<0.05$ level of significance. The soybean equivalent yield was calculated converting the cost of maize and pigeon pea to cost of soybean.

3. RESULTS AND DISCUSSION

Runoff and Soil Loss

Runoff and soil loss through runoff have been determined under different crop covers in both the years (Table 1). The average runoff and soil loss of two years varied from 17.5 to 27.5% of total annual rainfall and 1.34 to 2.87 t ha^{-1}, respectively. The runoff and soil loss was significantly higher under cultivated fallow (208 mm and 2.87 t ha^{-1}) as compared to sole as well as intercrops. In case of sole crops, the runoff and soil loss was significantly the lowest (132 mm and 1.48 t ha^{-1}) under soybean and the highest (177 mm and 2.15 t ha^{-1}) was under pigeon pea followed by maize crop (167 mm and 1.99 t ha^{-1}), respectively. Similarly, in case of intercrops, the lowest runoff and soil loss (132 mm and 1.34 t ha^{-1}) was recorded under soybean + pigeon pea (2:1) and the highest (140 mm and 1.6 t ha^{-1}) in maize + pigeon pea(1:1). However, all the intercrop treatments were statistically at par. The trend of runoff and soil loss was in the order; cultivated fallow > pigeon pea > maize > maize + pigeon pea (1:1) > soybean + maize (1:1) > soybean + pigeon pea (2:1) > soybean. Among sole crops, the per cent reduction of runoff and soil loss was the highest (37% and 48%) under soybean and the lowest (15% and 25%) in pigeon pea. But under intercrops, the highest per cent reduction of runoff and soil loss was under soybean + pigeon pea (37% and 53%) and the lowest was in maize + pigeon pea (33 and 44%). The runoff and soil loss was less due to more canopy coverage under soybean sole and intercrops as supported by crop cover percent. The trend of crop cover percent was in the order of; sole soybean >soybean + pigeon pea > soybean + maize > maize + pigeon pea > maize > pigeon pea at 35 days after sowing of crops (Table 1). But soil loss was more in cultivated fallow due to bare soil surface. Narayan and Bhusan (2000) also observed higher runoff and soil loss under caster crops in comparison to cluster bean, green gram, sesame, pearl millet and cowpea in deep alluvial soils of Agra. Kale *et al*. (1998) and Cinnirella *et al*. (1998) also reported low erosion losses under legumes crops than the widely spaced crops such as maize or caster. Lakaria *et al*. (2011) also reported that the crops like cluster bean, sesame, green gram and groundnut recorded less soil loss and thus helped conserve the soil resource. Similar findings have also reported by Arnaez *et al*. (2007), Kothayari *et al*. (2004) and Mtakwa *et al*. (2006).

Nutrients Losses

The data on Soil Organic Carbon (SOC) and total NPK losses are presented in Table 2. The losses with respect to soil organic carbon, total nitrogen, total phosphorus and total potassium varied from 11.22 to 23.55, 2.44 to 5.59, 0.33 to 0.65 and 10.03 to 23.91 kg ha^{-1}, respectively. Among the sole crops, the losses of SOC and total NPK were higher in pigeon pea crop (18.45, 4.42, 0.59 and 19.14 kg ha^{-1}) and the lowest (12.06, 2.44, 0.35 and 13.84 kg ha^{-1}) in soybean crop followed by maize. In case of intercrops, the maximum respective losses (14.81, 3.17, 0.42 and 10.43 kg ha^{-1}) were recorded in maize + pigeon pea (1:1) and minimum in soybean + pigeon pea (2:1) (11.22, 2.44, 0.33 and 10.03 kg ha^{-1}). However, soybean (sole) and intercrop treatments were statistically at par. Among the treatments, SOC and total NPK losses (23.55, 5.59, 0.65 and 23.91 kg ha^{-1}) were significantly highest under cultivated fallow plot over the sole as well as intercrops. Among sole crops reduction in

Table: 1
Average runoff and soil loss under different crop covers (mean of two years)

Cropping system	Runoff (mm)	Soil loss (t ha^{-1})	% reduction over cultivated fallow)		Crop cover (%)
			Runoff	Soil loss	
Soybean	132	1.48	37	48	56
Maize	167	1.99	20	31	27
Pigeon pea	177	2.15	15	25	17
Soybean + Maize (1:1)	135	1.48	35	48	38
Soybean + Pigeon pea (2:1)	132	1.34	37	53	41
Maize + Pigeon pea (1:1)	140	1.60	33	44	34
Cultivated fallow	208	2.87	0	0	--
CD (P=0.05)	29	0.44	--	--	--

Table: 2
Average soil nutrient losses under different crop covers (mean of two years)

Cropping system	Nutrient losses (kg ha^{-1})				% reduction in nutrients losses over cultivated fallow			
	SOC	Total-N	Total-P	Total-K	SOC	Total-N	Total-P	Total-K
Soybean	12.06	2.44	0.35	13.84	49	56	46	42
Maize	17.95	4.13	0.50	17.78	24	26	23	25
Pigeon pea	18.45	4.42	0.59	19.14	22	21	10	20
Soybean + Maize (1:1)	12.95	2.85	0.35	11.73	45	49	46	51
Soybean + Pigeon pea (2:1)	11.22	2.44	0.33	10.03	52	56	49	58
Maize + Pigeon pea (1:1)	14.81	3.17	0.42	10.43	37	43	35	56
Cultivated fallow	23.55	5.59	0.65	23.91	0	0	0	0
CD (P=0.05)	4.39	1.13	0.09	4.28	--	--	--	--

SOC and total NPK losses were the highest (49, 56, 46 and 42%) in sole soybean and the lowest (22, 21, 10 and 20%) under pigeon pea as a sole crops. In case of intercrops, maximum per cent reduction of SOC and total NPK losses was in soybean + pigeon pea (2:1) (52, 56, 49 and 58%) and lowest (37, 43, 35 and 56%) was under maize + pigeon pea. In general among the crop treatments, the maximum reduction of nutrient losses was in soybean and it intercrops and lowest was in sole pigeon pea and maize. Lakaria *et al*. (2010) have also reported that the losses of organic carbon, total nitrogen, available phosphorus and potassium were highest under cultivated fallow due to bare soil surface but cover crop of groundnut allowed less nutrient losses, whereas caster resulted in maximum nutrient losses.

Changes in Soil Properties

The soil properties under different crop covers after end of two years of experiment are presented in Table 3. The soil pH, available NPK, bulk density (BD), mean weight diameter (MWD), infiltration rate (IR), crack volume (CV) and penetration resistance (PR) were not found to had any significant difference among the treatments but these parameters were relatively improved as compared to cultivated fallow. But soil organic carbon (SOC) content was significantly higher under soybean + pigeon pea (2:1) followed by soybean + maize (1:1) and maize + pigeon pea (1:1) intercropping as compared to sole soybean, maize and pigeon pea. The poor fertility under cultivated fallow may be attributed to highest loss of nutrients and absence of organic residues, since the plots were kept free of weeds throughout the period of experiment. However, improvement in soil organic carbon under intercropped plots might be due to relatively higher root biomass and the lowest loss of nutrient from the surface when compared with cultivated fallow. Prasad *et al*. (1993) reported that castor + green gram (1:2) intercropping showed higher value of organic carbon and available N and K than sole castor probably due to lower loss of nutrients and addition of nitrogen rich root mass of green gram in the soil. Simple correlation was worked out among soil properties (Table 4). Results indicated that the soil bulk density showed significantly positive correlation with crack volume but significantly negative correlation with mean weight diameter, available nitrogen and phosphorus. The mean weight diameter showed significantly negatively

Table: 3
Impact of crop covers on selected soil properties

Treatment	pH	Soil organic carbon (%)	Available (kg ha^{-1}) N	P	K	Bulk density (Mg m^{-3})	Mean weight diameter (mm)	Crack volume (m^3 ha^{-1})	Penetration résistance (M Pa)	Infiltration rate (cm hr^{-1})
Soybean	7.98	0.55	138	20.8	368	1.32	0.94	22.5	1.28	1.89
Maize	7.96	0.57	136	16.9	364	1.34	0.90	25.0	1.31	1.99
Pigeon pea	7.95	0.57	133	16.7	357	1.36	0.87	27.4	1.26	2.20
Soybean + Maize (1:1)	8.00	0.66	134	18.6	372	1.34	0.89	27.5	1.35	2.12
Soybean + Pigeon pea (2:1)	7.97	0.68	135	16.0	374	1.35	0.89	28.4	1.26	2.14
Maize + Pigeon pea (1:1)	8.02	0.66	135	16.7	375	1.35	0.89	27.4	1.31	2.02
Cultivated fallow	7.97	0.53	132	15.4	324	1.37	0.82	33.3	1.25	1.86
CD (P=0.05)	NS	0.045	NS	NS	NS	NS	NS	NS	NS	NS

Table: 4
Correlation coefficient (r) values of soil properties

	pH	OC	BD	Avail. N	Avail. P	Avail. K	MWD	CV	PR	IR
pH	1.00									
OC	0.50	1.00								
BD.	-0.24	- 0.06	1.00							
Avail N	0.26	- 0.03	-0.93*	1.00						
Avail P	0.26	- 0.28	-0.77*	0.72	1.00					
Avail K	0.73	0.69	-0.34	0.32	0.12	1.00				
MWD	0.17	0.01	-0.92*	0.86*	0.73	0.06	1.00			
CV	0.01	0.17	0.83*	-0.89*	-0.56	0.07	-0.91*	1.00		
PR	0.49	0.45	-0.32	0.02	0.34	0.54	0.19	0.19	1.00	
IR	0.05	0.63	-0.35	0.16	-0.03	0.06	0.51	-0.33	0.32	1.00

*Significant at 5% level (df = n-2)

correlation with crack volume and available nitrogen. Almost similar findings were reported by Bandhyopadhyay *et al*. (2003) where the bulk density of surface soil positively influenced width and length of the cracks.

Soil Moisture Retention

The average soil moisture retained at harvest stage of soybean and maize of both years is presented in Fig. 2. In both the years, acute moisture stress occurred in soil due to low rainfall and progressive desiccation of surface layers in the month of October. The soil moisture content increased with increasing soil depth. In 0-15 cm soil depth, the soil moisture content was significantly higher in soybean and maize crops at harvesting stage as compared intercrops at vegetative stage and cultivated fallow with weed free plot. In surface layer, the soil moisture content was less under cultivated fallow due to bare soil but in sub surface layer the higher soil moisture content was recorded because of no uptake of water in absence of crops. But in case of 15-30 cm soil depth, the soil moisture was significantly higher under soybean, maize and cultivated fallow and lowest under pigeon pea and intercrops. The depletion of soil moisture was highest from sole pigeon pea and pigeon pea with combination of other crops in all the soil depths at harvest of maize and soybean. This might be due to higher extraction

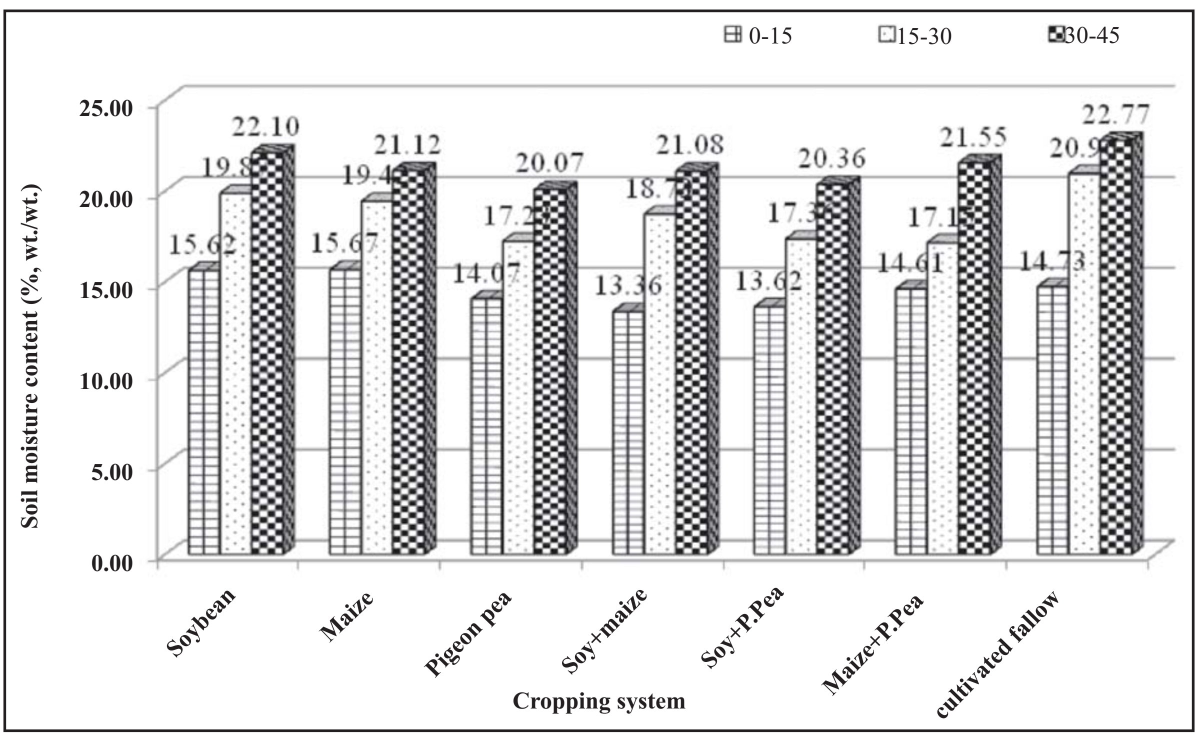


Fig. 2. Average soil moisture content (%) at harvest stage of soybean at different soil depths

of moisture by pigeon pea which was approaching vegetative stage when soybean and maize were at harvest stage. However, there was no difference in moisture at 30-45 cm soil depth. Hati *et al*. (2008) reported that the water extraction was higher by pigeon pea and pigeon intercrop after the withdrawal of monsoon due to vegetative stage of pigeon pea crop.

Soybean Equivalent Yield (SEY)

Yield data of different crops in term of SEY is presented in Table 5. In case of sole crops, the average soybean equivalent yield was significantly higher under maize crop (2597 kg ha^{-1}) and significantly lowest in sole soybean crop (326 kg ha^{-1}) followed by pigeon pea crop. But in case of intercrops, the higher soybean equivalent yield was recorded under maize + pigeon pea crops (5164 kg ha^{-1}) and the lowest in soybean + pigeon pea crop (1828 kg ha^{-1}) followed by maize + soybean. Among the sole as well as intercrop treatments, the maize or combination of maize with soybean or pigeon pea recorded significantly higher soybean equivalent yield as compared to rest of the treatments. The soybean yield was less in the both the years. The reason could not be found for lower yield of soybean. In general, the intercrops are the best option for enhancing the productivity of the system in comparison to sole crops. The chances of failure of sole crops are more while intercrops can minimize the risk under rainfed conditions. Similarly, Subudhi (2011) reported that intercropping of ground nut with pigeon pea planted along contour (2% slope) gave the highest rice equivalent yield (59 q ha^{-1}) and lowest soil loss (6.27 t ha^{-1}) and lowest runoff of 230 mm followed by pigeon pea and groundnut strip cropping planted along the contour with rice equivalent yield of 54.43 q ha^{-1} at Phulbani of Kandhamal in Odisha.

4. CONCLUSIONS

The study revealed that crop covers under vertisol recorded wide variation in runoff, soil and nutrients losses. The study recorded maximum soil loss (2.87 t ha^{-1}) under cultivated fallow whereas 1.48 to 1.60 under sole soybean and intercrops. However, these values indicated that erosion limit were very well below the critical limit of < 5 t ha^{-1} which has been classified as very slight erosion category. In this region, the soybean crop is the one of the better option to reduce runoff, soil and nutrient losses because of more crop covers but yield of soybean crops is declining due to some reason since several years. The intercrops namely soybean + maize, soybean + pigeon pea and maize + pigeon pea were also reduced runoff, soil and nutrients losses to the same level as soybean crop. Similarly, the soybean equivalent yield (SEY) was also significantly higher under maize + pigeon pea (5164 kg ha^{-1}) and soybean + maize (3193 kg ha^{-1}) as compared to sole soybean yield. Hence, maize + pigeon pea (1:1) intercrop is the best option in reducing runoff, soil and nutrient losses and enhancing crop productivity. Therefore, adoption of different crop covers/intercrops coupled with proper soil conservation measures are recommended for controlling erosion, reducing of soil and nutrients losses, sustaining crop productivity as well as improving soil health in vertisol of central India.

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Table: 5
Soybean equivalent yield (kg ha^{-1}) of different crops

Cropping system	2010	2011	Mean
Soybean	324	328	326
Maize	3201	1991	2596
Pigeon pea	2151	2057	2104
Soybean + Maize (1:1)	4378	2008	3193
Soybean + Pigeon pea (2:1)	1359	2297	1828
Maize + Pigeon pea (1:1)	5902	4426	5164
CD (P=0.05)	1222	1361	786

SEY calculated based on Minimum Support Price (MSP) of year 2010-11 and 2011-12

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