Effect of Vetch Cover Crop and Green Manure on Runoff and Nutrient Loss and Yield of Chickpea in Gumara-Maksegnit Watershed

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Abstract

Cover crops play an important role in reducing runoff, soil loss, and nutrient loss. Farmers in Gumara-Maksegnit practices fallow during the rainy season for the preceding chickpea production system. A field experiment was conducted in 2014-2016 during the rainy season to evaluate the effect of vetch cover crop and green manure on runoff, soil and nutrient loss and yield of chickpea. The experiment contained four treatments including: 1) control plot (Farmers' practice: fallowing- without cover crop), 2) planting chickpea after removing vetch (Vicia sativa L.) with recommended DAP fertilizer, 3) planting chickpea after incorporating vetch as green manure to the soil without DAP fertilizer, 4) planting chickpea after incorporating vetch green manure to with the soil with half recommended DAP. The experiment was arranged in Randomized Complete Block Design with three replications. Each plot with an area of 36 m² was equipped with a runoff monitoring system. Vetch was planted as a cover crop at the onset of the rain in June and used as green manure. The analyses of variance showed that vetch cover crop reduced runoff volume by 18.9-27.3% and soil loss by 29-38.1% compared to fallowing (farmers practice). Vetch also reduced the nutrient loss (TN loss by 35.5-39%, available P by 34.5-50.42% and OM by 32.12-38.555%) compared to fallowing (farmers practice). Planting chickpea after incorporating vetch as green manure reduced runoff volume from 33.7-24.49 m^3 ha^{-1}, soil loss from 290.61-180.04 kg ha^{-1}, TN loss from 0.31-0.189 kg ha^{-1}, phosphorus loss from 1.19-0.59 g ha^{-1} and OM loss from 7.47-4.59 kg ha^{-1} and increased crop yield by 9-24% compared to the control. Furthermore 4.62 to 18.44 t ha^{-1} vetch biomass can be produced compared to fallowing. Therefore, vetch cover incorporated to the soil as green manure is recommended for chickpea production system for the aforementioned benefits.

Keywords: *cover crop, green manure, runoff, soil loss, vetch*

Introduction

Plant residues reduce the impact of raindrops that otherwise would detach soil particles and make them prone to erosion. A cover crop is a crop planted primarily to manage soil fertility, soil quality, water, weeds, pests, and diseases in an agro-ecosystem (Lu *et al*., 2000). Farmers choose to grow and manage specific cover crop types based on their own needs and goals, influenced by the biological, environmental, social, cultural, and economic factors of the food system in which farmers operate (Snapp *et al.*, 2005). One of the primary use of cover crops when incorporated as green manure is to increase soil fertility. Often, green manure crops are grown for a specific period, and then plowed under before reaching full maturity in order to improve soil fertility and quality. They are used to manage a range of soil macronutrients and micronutrients. Of the various nutrients, the impact that covers crops has on nitrogen management has received the most attention from researchers and farmers, because nitrogen is often the most limiting nutrient in crop production (Sutton *et al.*, 2011).

Cover crops can also improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time. Increased soil organic matter enhances soil structure, as well as the water and nutrient holding and buffering capacity of the soil (Patrick *et al.*, 1957). Although cover crops can perform multiple functions in an agro ecosystem simultaneously, they are often grown for the sole purpose of preventing soil erosion. Dense cover crop stands physically slow down the velocity of rainfall before it contacts the soil surface, preventing soil splashing and erosive surface runoff (Römkens *et al.*, 1990). Cover crop biomass acts as a physical barrier between rainfall and the soil surface, allowing raindrops to steadily trickle down through the soil profile. The protective canopy formed by a cover crop reduces the impact of raindrops on the soil surface thereby decreasing the breakdown of soils aggregates. This greatly reduces soil erosion and runoff and increases infiltration. Decreased soil loss and runoff translate to reduced transport of valuable nutrients, pesticides, herbicides, and harmful pathogens associated with manure from farmland that degrades the quality of streams, rivers and water bodies and poses a threat to human health.

By reducing soil erosion, cover crops often also reduce both the rate and quantity of water that drains off the field, which would normally pose environmental risks to waterways and ecosystems downstream (Dabney *et al.*, 2001). Gómez *et al.* (2009) and Joyce *et al.* (2002)

reported that cover crops have a significant impact on increasing infiltration capacity and subsequently it reducing the amount of runoff and soil loss. Cover crops are generally included in cropping systems as nutrient management tools (Ruffo and Bollero, 2003). Cover crops can be leguminous or non-leguminous. As vetch is one of legume cover crops, it is used as a source of nitrogen (N) for the following cash crop (Smith *et al.*, 1987) while grasses are mainly used to reduce NO3 leaching and erosion (Meisinger *et al.*, 1991). Biological fixation by leguminous crops offers the potential to reduce the need for N fertilizers for the succeeding crop (Ladha *et al.*, 2004). A bicultural of a legume and grass is used with the intention of providing both benefits simultaneously (Ranells and Wagger, 1996).

When a cover crop is managed for its contribution to soil nitrogen, the application of nitrogen fertilizer for the subsequent crop may be less, thereby lowering costs of production, reduced nitrogen losses to the environment and reducing the use of purchased nitrogen fertilizer that is produced using fossil fuels. Planting cover crops before or between main crops can improve soil physical, chemical, and biological properties and consequently lead to improved soil health and yield of principal crops. Leaving cover crops as surface mulches in no-till crop production systems has the advantage of increasing nitrogen economy (Smith *et al.*, 1987; Frye *et al.*, 1988) conserving soil moisture (Morse, 1993), reducing soil erosion (Langdale *et al.*, 1991), improving soil physical properties (Blevins and Frye, 1993), increasing nutrient retention (Staver and Brinsfield, 1998; Dinnes *et al.*, 2002), increasing soil fertility (Cavigelli and Thien, 2003), suppressing weeds (Creamer *et al.*, 1996; Creamer and Baldwin, 2000), reducing diseases and insects (Ristaino *et al.*, 1996), reducing global warming potential (Robertson *et al.*, 2000), and increasing crop yields (Triplett *et al.*, 1996). Planting cover crop during the fallow period in Gumara-Maksegnit watershed is an unconventional or precious activity that needed to introduce and adopt for farmers. It is better to cover the land with the cover crop as compared to leaving the land fallowing. There was no finding or it is a site-specific related to the impact of vetch cover crop on runoff, soil loss and nutrient loss in the experimental area. Therefore, this study was conducted to evaluate the effect of vetch cover crop and green manure on runoff, soil loss, soil chemical properties and yield of chickpea in North Gondar zone, Gumara-Maksegnit watershed. The main objective of the research activity was to evaluate the effect of cover crop and green manure on runoff, soil loss, soil nutrient loss and yield of chickpea in the study area.

Materials and Methods

Description of the study Area

The study area is located in the northwest part of Amhara National Regional State; North Gondar zone at Gumara-Makegnit watershed. The watershed is located at about 45 km southwest of Gondar near Makegnit town. It covers an area of 53.7 square kilometers and located at 12^0 ^{0} ^{0} ^{0} longitude (Figure 1). -2016 cropping season. The altitude of the experimental site ranges from 1923 to 2851 m above mean sea level. The mean annual rainfall in the area is about 1052 mm and it is seasonal, erratic and uneven in distribution (Addis and Klik, 2015). The mean maximum temperature of the area is about 28.5 °C and while the mean minimum temperature is about 13.3°C. The soil types are predominately Cambisol and Leptosol which are found in the upper and central part of the watershed, whereas Vertisol is found in the lower catchment near the main outlet in which the experiment was undertaken (Addis *et al.*, 2015).

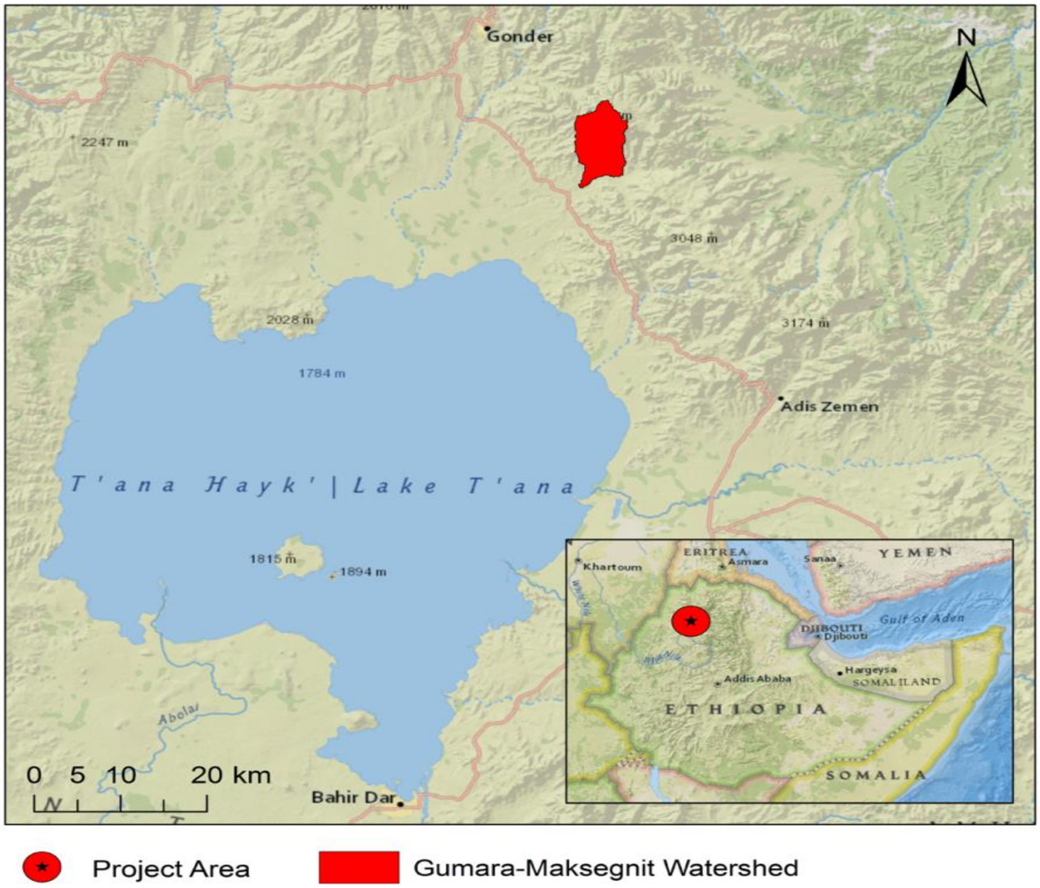

Figure 1. Location of the study area (Addis et al., 2015)

Experimental setup

have 7.2% slope. The Four treatments were arranged in a randomized complete block design with three replications (Figure 2). The treatments were:

1. Control plot or
2. Chickpea planted with recommended Di-ammonium phosphate (DAP) fertilizer after the harvesting of vetch cover crop,
3. Chickpea planted after vetch cover crop was incorporated with the soil as green manure and
4. Chickpea planted after vetch cover crop was incorporated with the soil as green manure and with half Di-ammonium Phosphate (DAP) application.

The test crop was chickpea planted in early September. Before planting chickpea, vetch was planted in June as cover and green manure crop during the rainy season by substituting the fallow practice of farmers. Vetch was planted in rows at the seed rate of 25 kg ha^{-1}. Later it was plowed under and incorporated as green manure a week before planting chickpea.

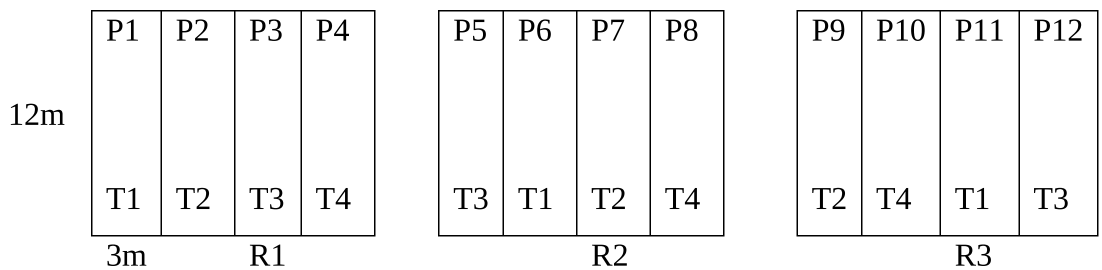

Figure 2. Treatment layout with site replication

Runoff, Soil loss and Nutrient loss sampling

Each runoff plots were bounded by the iron sheet. The overland flow was guided and channeled using PVC tube into a metal tanker to collect and measure the runoff during the selected rain fall events. The average of selected 5 rainfall events in 2014 and 9 rainfall events in 2015 and 2016 was taken for analyzing the soil and nutrient loss from plots. Hence the rainfall and runoff events

rainfall runoff and events was changed into one representative rainfall and runoff event for the analysis of all needed parameters. So, all the analysis was made per unit (1) event which was the mean of different events in each experimental year. 5.5 liters volume of runoff sample was taken during each event and then filtered and weighed for sediment and nutrient analysis. Two-liter volume of runoff sample was used for sediment analysis and the rest 3.5 litter was used for nutrient analysis. All soil loss and nutrient loss data obtained from laboratory analysis by using this sample were compiled and inferred to the whole soil and nutrient loss data collected from each runoff plots. Organic matter was determined from organic carbon according to Walkley & Black method (Schnitzer, 1982) and the OC result obtained from laboratory analysis was multiplied by 1.724 to provide organic matter. Available P was measured in Parts per million (ppm). Total nitrogen was analyzed by the Kjeldahl method (Bremner and Mulvaney, 1982). The other volume of runoff collected in a metal tanker was measured and drained away from the tanker and clean the tanker for the sampling of the next day. The total volume of runoff in each plot that was averaged from different events and assumed in one event is shown in Table 1 below.

(A) (B)

Figure 2. Design and layout of experiment on the ground: (A) before planting and (B) after planting

(A) (B)

Figure 3. (A) fallow versus , (B) dense vetch cover crop plots

Table 1. Mean runoff, soil loss and nutrient loss in 2015 and 2016 rainy season)

Sampling year	Runoff plots	Rainfall (mm)	Total volume (liter)	Runoff depth (mm)	Runoff coefficient (C)	Sediment loss g/l	% Total N	Available P/PPM	% O.M
2014	RP-1	36.98	122.42	3.40	0.09	13.95	0.13	0.91	2.14
	RP-2	36.98	125.52	3.49	0.09	10.39	0.10	2.07	2.46
	RP-3	36.98	113.44	3.15	0.09	12.00	0.12	1.58	2.49
	RP-4	36.98	115.19	3.20	0.09	6.23	0.11	1.10	2.29
	RP-5	36.98	104.71	2.91	0.08	7.59	0.11	1.34	2.75
	RP-6	36.98	110.78	3.08	0.08	12.15	0.12	2.36	2.50
	RP-7	36.98	105.78	2.94	0.08	10.98	0.12	2.06	2.53
	RP-8	36.98	83.42	2.32	0.06	7.50	0.12	2.02	2.73
	RP-9	36.98	100.82	2.80	0.08	7.45	0.14	2.08	2.61
	RP-10	36.98	123.13	3.42	0.09	12.79	0.12	1.99	2.92
	RP-11	36.98	157.43	4.37	0.12	8.23	0.10	2.13	2.98
	RP-12	36.98	125.56	3.49	0.09	4.14	0.15	1.05	2.19
2015	RP-1	29.11	61.72	1.71	0.06	5.46	0.10	6.16	2.38
	RP-2	29.11	56.89	1.58	0.05	5.63	0.09	5.92	2.37
	RP-3	29.11	55.83	1.55	0.05	6.55	0.09	5.18	2.29
	RP-4	29.11	48.94	1.36	0.05	7.96	0.08	5.54	2.15
	RP-5	29.11	57.33	1.59	0.05	6.15	0.09	5.18	2.31
	RP-6	29.11	68.89	1.91	0.07	9.77	0.10	6.16	1.90
	RP-7	29.11	69.28	1.92	0.07	6.01	0.09	5.41	2.18
	RP-8	29.11	56.72	1.58	0.05	8.02	0.08	5.54	1.98
	RP-9	29.11	63.43	1.76	0.06	6.82	0.09	5.33	2.11
	RP-10	29.11	65.67	1.82	0.06	7.60	0.08	5.54	2.42
	RP-11	29.11	70.67	1.96	0.07	6.72	0.10	6.18	2.11
	RP-12	29.11	56.28	1.56	0.05	7.05	0.09	5.21	2.16
2016	RP-1	44.75	151.72	4.21	0.09	5.46	0.07	5.73	2.75
	RP-2	44.75	123.87	3.44	0.08	5.63	0.08	4.88	2.23
	RP-3	44.75	84.17	2.34	0.05	6.55	0.10	3.13	2.54
	RP-4	44.75	99.94	2.78	0.06	7.96	0.09	5.39	2.50
	RP-5	44.75	97.22	2.70	0.06	8.15	0.11	4.89	3.03
	RP-6	44.75	188.11	5.23	0.12	9.77	0.09	6.85	3.11
	RP-7	44.75	127.00	3.53	0.08	6.58	0.08	6.07	2.22
	RP-8	44.75	118.67	3.30	0.07	9.02	0.09	5.64	2.37
	RP-9	44.75	112.67	3.13	0.07	6.82	0.07	4.99	2.21
	RP-10	44.75	110.00	3.06	0.07	4.26	0.08	4.82	2.18
	RP-11	44.75	160.11	4.45	0.10	5.72	0.12	4.99	2.44
	RP-12	44.75	98.94	2.75	0.06	7.05	0.07	5.11	2.66

Crop yield measurement

Chickpea was planted in 2014 and 2015 cropping seasons but not in 2016. To investigate the effects of vetch cover crop on crop response, chickpea yield was collected and measured from 18 m^2 harvestable sizes at the middle of each runoff plots at the end of the growing season. Vetch biomass also collected and measured to compare the cover crop treatment with non-cover crop (fallow) treatment, because the cover crop has an additional fodder value for cattle.

Data Analysis Procedures

As explained earlier in the experimental setup, the sampling plots were arranged in randomized complete block design replicated three times. The data obtained from field measurement and laboratory analysis were analyzed by SAS software version 9.0. The soil and nutrient loss and crop yield were subjected to analysis of variance using the general linear model procedure of the statistical analysis system. When the analysis of variance (ANOVA) showed significant differences (at $p\ \ 0.05$) due to cover crop and fallowed treatments, a mean separation for each parameter was made using the least significant difference (LSD). A simple graphical representation also used to explain the difference in vetch biomass of cover crop treatments.

Result and Discussions

Effect of Vetch Cover Crop on Runoff and Soil loss

show any significant differences ($p>0.05$) between treatments (Table 2). But numerically, the higher runoff and soil loss was observed in the control plot as compared to vetch cover crop treatments. The control plot produced higher runoff volume (36.17 m^3 ha^{-1}) and the cover crop treatments produced lower runoff volume which ranges from 29.79-31.83 m^3 ha^{-1}. The higher soil loss 402.6 kg ha^{-1} also observed in fallow treatment as compared to the vetch covered treatments which range from 247.82-297.86 kg ha^{-1}. This implies that vetch cover crop reduced runoff volume by 14.9% and soil loss by 32.47% relative to the fallow treatment. As shown in Table 3 below in 2015, runoff t

shown in Table 7, the higher runoff volume (18.64 m^3 ha^{-1}) was observed in the control plot, while the cover crop treatments were recorded lower (16.37 m^3 ha^{-1} on average) runoff volume. Absolutely, higher sediment (137.46 kg ha^{-1}) was lost in control treatment and lower sediment (on average, 111.96 kg ha^{-1}) was lost in treatments covered by vetch. In 2016, there tments in runoff volume and depth, but

37.9% soil loss reduction was observed numerically (Table 8). The higher runoff volume (46.29 m^3 ha^{-1}) was removed in the fallow plot, while lower runoff volume (25.96-33.66 m^3 ha^{-1}) was lost in vetch cover crop treatments. This resulted in vetch reduce runoff volume by 35.2% as compared to fallowed land during the fallow season as shown in Table 6 to 9. In all the three years and the combined result showed that runoff depth was higher in the control plot as compared to treatments covered by vetch.

Table 2. The ANOVA for runoff volume (m3/ha), runoff depth (mm), sediment loss (kg/ha), and nutrient loss (N loss (kg/ha), Phosphorus loss (g/ha) and OM loss (kg/ha) in 2014

		Q		**Runoff (mm)**		**Sediment**		**TN**		**Available P**		**OM**	
Sources	**DF**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**
Treatment	3	23.78	0.31	0.24	0.31	14081.30	0.42	0.020	0.44	0.07	0.53	8.01	0.58
Replication	2	53.22	0.11	0.53	0.11	7397.58	0.59	0.008	0.68	0.00	0.96	1.54	0.88
Error	6	15.99		0.16		12735.65		0.019		0.083		11.34	

MS= means of squares, DF= degree of freedom, P= probability (indicator of significances), Q=runoff volume, TN=total nitrogen, P phosphorus, and OM=organic matter.

Table 3. The ANOVA for runoff volume (m^3/ha), runoff depth (mm), sediment loss (kg/ha), and nutrient loss (N loss (kg/ha), Phosphorus loss (g/ha) and OM loss (kg/ha)) for the average of 9 events in 2015

		Runoff volume		**Runoff depth**		**Sediment**		**TN**		**Available P**		**OM**	
Sources	**DF**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**
Treatment	3	5.98	0.05	0.06	0.05	732.01	0.31	0.001	0.17	0.05	0.12	0.20	0.38
Replication	2	6.14	0.06	0.06	0.06	1273.29	0.16	0.001	0.27	0.04	0.22	0.32	0.22
Error	6	1.32		0.013		496.38		0.001		0.018		0.16	

MS= means of squares, DF= degree of freedom, and P= probability (indicator of significances)

Table 4. The ANOVA for runoff volume (m^3/ha), runoff depth (mm), sediment loss (kg/ha), and N loss (kg/ha), *Phosphorus loss (g/ha) and OM loss (kg/ha)) in 2016*

		Runoff volume		Runoff depth		Sediment		TN		Available P		OM	
Sources	**DF**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**
Treatment	3	228.67	<0.001	2.28	<0.001	12271.40	0.15	0.013	0.10	0.78	0.15	14.91	0.16
Replication	2	25.69	0.07	0.26	0.07	18049.05	0.09	0.016	0.07	1.16	0.08	19.48	0.11
Error	6	6.15		0.062		4869.58		0.004		0.3		5.99	

Where, MS= means of squares, DF= degree of freedom, and P= probability (indicator of significances)

Table 5. The overall combined ANOVA for runoff volume (m^3/ha), runoff depth (mm), sediment loss (kg/ha), and N loss (kg/ha), Phosphorus loss (g/ha) and OM loss (kg/ha).

		Runoff volume		Runoff depth		Sediment		TN		Available P		OM	
Sources	**DF**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**	**MS**	**P**
Treatment	3	155.76	<0.0001	1.55	<0.0001	21120.00	0.04	0.027	0.04	0.59	0.02	15.82	0.08
Year	2	1057.61	<0.0001	10.62	<0.0001	106802.61	<0.0001	0.190	<0.0001	1.99	0.00	85.31	0.00
Error (year)	6	28.35	0.016	0.28	0.016	8906.64	0.24	0.009	0.39	0.40	0.033	7.11	0.34
year*Treatment	6	51.34	0.0008	0.51	0.0008	2982.36	0.8	0.003	0.85	0.16	0.369	3.65	0.71
Error	18	7.83		0.08		6033.87		0.008		0.13		5.83	

MS= means of squares, DF= degree of freedom, Q=runoff volume, TN=total nitrogen, P phosphorus, and OM=organic matter.

In the combined analysis, all runoff volume, depth, and soil loss showed significant variation at $p<0.05$ among the treatment means. Runoff volume and runoff depth also showed highly significant variation among treatment means (Table 5). As shown in table 9, higher runoff volume (33.7 m^3 ha^{-1}) and soil loss (290.61 kg ha^{-1}) were lost in control plot, while the lower runoff volume on average about 25.72 m^3 ha^{-1} and soil on average about 196.65 kg ha-1 was lost in vetch covered treatments. In overall combined means surprisingly higher reduction (38.05%) of soil loss was observed in third treatment (Chickpea is planted after vetch cover crop incorporated with the soil as green manure). As indicated by Römkens *et al.* (1990), dense stands of vetch cover crops in treatment two to four slow down the velocity of rainfall drops before it contacts the soil surfaces and then preventing soil splashing and reduces erosive surface runoff. This experiment showed that covering the land using vetch cover crop was the effective way to reduce the surface runoff and soil loss during the fallow season and fallowing the land without cover crop enhances runoff and soil loss.

Table 6. Mean runoff depth (mm), sediment loss (kg/ha), and nutrient loss in 2014

Treatment	**Q (m^3 ha^{-1})**	**Runoff (mm)**	**Sediment (kg ha^{-1})**	**TN (kg ha^{-1})**	**Available P (g ha^{-1})**	**OM (kg ha^{-1})**
T1	36.17	3.62	402.69	0.48	0.69	10.08
T2	30.75	3.08	297.86	0.34	0.61	7.51
T3	31.83	3.18	247.82	0.30	0.35	6.21
T4	29.79	2.98	270.11	0.31	0.48	7.36
CV $_{(\%)}$	12.44	12.44	37.05	38.30	54.01	43.22
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns

ns=non-

T2=Chick pea planted with recommended Di-ammonium phosphate (DAP) fertilizer after the harvesting of vetch cover crop, T3=Chickpea planted after vetch cover crop was incorporated with the soil as green manure and T4=Chickpea planted after vetch cover crop was incorporated with the soil as green manure and with half Di-ammonium Phosphate (DAP) application. This is considered for all tables.

Table 7. Mean runoff depth (mm), sediment loss (kg/ha), N loss (kg/ha), Phosphorus loss (g/ha) and OM loss (kg/ha)) in 2015

Treatment	Q (m^3 ha^{-1})	Runoff (mm)	Sediment (kg ha^{-1})	TN (kg ha^{-1})	Available P (g ha^{-1})	OM (kg ha^{-1})
T1	18.64^{a}	1.86^{a}	137.49	0.13	0.85	2.85
T2	17.55^{ab}	1.75^{ab}	108.25	0.10	0.60	2.39
T3	15.69^{b}	1.57^{b}	103.26	0.09	0.54	2.32
T4	15.87^{b}	1.59^{b}	124.36	0.10	0.69	2.73
CV $_{(\%)}$	6.80	6.74	18.83	21.76	20.52	15.61
LSD $_{(0.05)}$	*	*	ns	ns	ns	ns

-significant (p >0.05). Values with different letters within the same column showed significant variation between

Table 8. Mean runoff depth (mm), sediment loss (kg/ha), N loss (kg/ha), Phosphorus loss (g/ha) and OM loss (kg/ha) in 2016

Treatment	Q (m^3 ha^{-1})	Runoff (mm)	Sediment (kg ha^{-1})	TN (kg ha^{-1})	Available P (g ha^{-1})	OM (kg ha^{-1})
T1	46.29^{a}	4.63^{a}	331.66	0.31	2.03	9.47
T2	33.66^{b}	3.37^{b}	213.03	0.17	1.14	4.73
T3	25.96^{c}	2.60^{c}	189.03	0.18	0.85	5.24
T4	30.43^{bc}	3.05^{bc}	216.14	0.19	1.17	5.13
CV $_{(\%)}$	7.28	7.32	29.39	29.61	42.32	39.85
LSD $_{(0.05)}$	**	**	ns	ns	ns	ns

-significant (p >0.05). Values with different letters

Table 9. Mean runoff depth (mm), sediment loss (kg/ha), N loss (kg/ha), Phosphorus loss (g/ha) and OM loss (kg/ha) combined over years.

Treatment	Q (m^3 ha^{-1})	Runoff (mm)	Sediment (kg ha^{-1})	TN (kg ha^{-1})	Available P (g ha^{-1})	OM (kg ha^{-1})
1	33.70^{a}	3.37^{a}	290.61^{a}	0.31^{a}	1.19^{a}	7.47
2	27.32^{ab}	2.73^{ab}	206.38^{b}	0.202^{b}	0.78^{ab}	4.88
3	24.49^{b}	2.45^{b}	180.04^{b}	0.187^{b}	0.59^{b}	4.59
4	25.36^{b}	2.54^{b}	203.54^{b}	0.20^{b}	0.78^{ab}	5.07
CV $_{(\%)}$	10.09	10.10	35.28	39.22	44.00	43.88
LSD $_{(0.05)}$	**	**	*	*	*	ns

-significant (p >0.05). Values with different letters within the same column showed significant variation between

Effect of Vetch Cover Crop on Nutrient Loss

However, numerical or absolute variation was observed between treatment means in all three years. As shown in table 6, 7 and 8, the higher TN (0.48, 0.13, and 0.31 kg ha^{-1}) loss was recorded in fallowed (control) plot as compared to vetch cover crop treatments which range from 0.3-0.34, 0.09-0.10 and 0.17-0.19 kg ha^{-1} in the consecutive three years respectively. The loss of available phosphorus in the control plot was ranged from 0.69-2.03 g ha^{-1}, while in the treatments covered by vetch it was ranged from 0.35-1.17 g ha^{-1} in all the three years. Organic matter loss also higher in control plot like other nutrient parameters. For example, in 2016, OM loss in control plot was about 9.47 kg ha^{-1}, while in the vetch covered treatments it reduced on average to 5.03 kg ha^{-1} which means reducing OM loss by 46.9% relative to control plot. When coming to the overall combined means, TN and available P showed

($p>0.05$) variation between treatment means. The higher (0.31 kg ha^{-1} per event) mean values of TN loss was recorded in control plot and vetch cover crop treatments resulted in 0.2, 0.18, and 0.2 kg ha^{-1} per event for T2, T3, and T4 respectively. As explained above in runoff and soil loss, the third treatment (Chickpea is planted after vetch cover crop incorporated with the soil as green manure) was the winner of all other treatments. It reduced TN loss 61%, available P loss by 50% and OM loss by 61.5% as it compared to the fallow practices in a unit rainfall event.

As explained by different findings (Blevins and Frye, 1993; Staver and Brinsfield, 1998; Ladha *et al.*, 2004), vetch cover crop is the effective way increasing nutrient retention, improving soil chemical properties and it also reduces the need of nitrogen and phosphorus fertilizers. (Mitchell and Tell, 1977) and (Ebelhar *et al.*, 1984) reported that cultivation of hairy vetch as a cover crop and green manure could reduce the use of chemical fertilizers. On the opposite side, leaving the land for fallowing during the rainy season exposed available nutrients to erosion through runoff. Reduction in soil erosion by cover crops is associated with increases in soil organic matter content which improve soil water infiltration and holding capacity. With more infiltration and less runoff from each rainfall event, soil erosion and nutrient loss are significantly reduced. Cover crops growing before chickpea planting increased surface cover, and anchor residue, and reduced rill erosion and subsequently prevent nutrients from leaching and erosion (Kaspar *et al.*, 2001).

Effect of Vetch Cover Crop on chickpea yield

show any significant (p>0.05) variation among the treatment means (table10). However, vetch cover crop treatments increased the yield of chickpea about 9-24% as compared to the control plot. Unfortunately, the yield of chickpea in both the two years was low, because there was a known shortage of rainfall during the experimental years in northwestern region site especially in 2015. The automatic and manual rain gauge recorded about 632 mm rainfall in 2014 and 533 mm rainfall in 2015 starting from June to September. Due to this shortage of rainfall, the crop was exposed to series drought. Normally, the second treatment (Chickpea planted with recommended Di-ammonium phosphate (DAP) fertilizer after the harvesting of vetch cover crop) was the winner according to the yield of chickpea, especially in 2014 cropping season. This might be occurred based on the fact that during the first year there was no significant variation between treatments because it is the start time. The higher yield in treatment to occur might be the result of the addition of recommended fertilizer. The real treatment variation was shown in the third treatment that had the appreciable result as compared to the control. Indicating that cover crop and green manure gradually enhanced crop yield.

Table 10. Mean chickpea grain yield combined over years (2014 and 2015)

	Grain Yield (kg ha-1)		
Treatment	**2014**	**2015**	**Combined**
T1	742.5	421.0	581.75
T2	768.7	671.0	719.85
T3	675.4	598.0	636.70
T4	600.2	665.7	632.95
CV $_{(\%)}$	27	23.25	25.13
LSD $_{(0.05)}$	ns	ns	ns

ns=non- T2=Chickpea planted with recommended Di-ammonium phosphate (DAP) fertilizer after the harvesting of vetch cover crop, T3=Chickpea planted after vetch cover crop was incorporated with the soil as green manure and T4=Chickpea planted after vetch cover crop was incorporated with the soil as green manure and with half Di-ammonium Phosphate (DAP) application. This is considered for all tables.

Biomass of vetch cover crop also used as fodder value for cattle. As shown in fig. 4 below, other parameters re

crop reduced runoff volume by 18.93-27.33% and soil loss by 28.98-38.05% with relative to the fallowed plot. Vetch also reduced the nutrient loss (total nitrogen loss by 35.5-39%, available phosphorus loss by 34.5-50.42% and organic matter content by 32.12-38.555 as compared to the control fallow practices. From vetch cover crop treatments, the third treatment (Chickpea planted after vetch cover crop was incorporated with the soil as green manure) was the winner to reduce runoff volume, soil loss and nutrient loss as it compared to the other three treatments. This treatment also reduced runoff volume from 33.7-24.49 m^3 ha^{-1}, soil loss from 290.61-180.04 kg ha^{-1}, TN loss from 0.31-0.189 kg ha^{-1}, phosphorus loss from1.19-0.59 g ha^{-1} and OM loss from 7.47-4.59 kg ha^{-1} as compared to fallow practices within a unit rainfall event.

treatment means. However, there was an absolute increment in yield of vetch cover crop treatments by 9-24 % an as compared to the control plot. It can also produce about 4.62 to 18.44 t ha^{-1} vetch biomass as compared to leave the land for fallowing. Based on this experiment vetch cover crop incorporated with the soil as green manure crop was the most outshine treatment in order to reduce runoff, soil loss, and nutrient loss, in which it is recommended to practice in similar agro-ecology. Although the finding in this experiment was very interesting, it could be needed to show each treatment separately with its economic analysis or cost-benefit analysis.

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