Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 14 Issue 7 Version 1.0 Year 2014
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Effects of Conservation Tillage Integrated with *'Fanya Juus' Structure* on Soil Loss in Northern Ethiopia

By Habtamu Muche, Fantaw Yimer & Melesse Temesgen
University of Gondar, Ethiopia

Abstract- In the Northern highlands of Ethiopia, surface runoff and soil loss have been identified as critical problems and the most limiting factors in agricultural production. Although different soil and water conservation mesures have been constructed by mobilizing the communities and resources, runoff has continued and put extra pressure on the structures. This study was initiated to investigate surface runoff and soil loss as affected by integration of conservation tillage with fanya juus' at plot level at Enerata kebele, East Gojjam Zone of Amhara Region. There were two tillage treatments (CT and TT) combined with newly constructed fanya juus with four replications. Runoff and soil loss were recorded at 38 rainfall event through three tied trenches within wheat (triticum vulgare) and tef (eragrostis tef) farm plots. Result showed that average runof f coefficients of 17.72% and 43.96% were recorded due to conservation tillage system from wheat and tef farm plots, respectevly. Thus, runoff coefficient induced 0.54 and 0.18 times reduced in soil loss from wheat and tef plots, respectively. Reduction of runoff volume and soil loss in the conservation tillage systems were attributed to retarded movement of water in the presence of invisible barriers in each furrow that are laid along the contour. The retarded movement of water resulted in increased infiltration and reduced soil loss. Overall, conservation tillage system has a paramount importance in reduction of soil loss while integrated with fanya juus' structures in cultivated lands.

Keywords: conservation tillage, fanya juus, runoff, soil loss.

GJSFR-D Classification : FOR Code: 050399

EFFECTSOFCONSERVATIONTILLAGEINTEGRATEDWITHFANYAJUUSSTRUCTUREONSOILLOSSINNORTHERNETHIOPIA

Strictly as per the compliance and regulations of :

Effects of Conservation Tillage Integrated with *'Fanya Juus' Structure* on Soil Loss in Northern Ethiopia

Habtamu Muche [α], Fantaw Yimer [σ] & Melesse Temesgen [ρ]

Abstract- In the Northern highlands of Ethiopia, surface runoff and soil loss have been identified as critical problems and the most limiting factors in agricultural production. Although different soil and water conservation mesures have been constructed by mobilizing the communities and resources, runoff has continued and put extra pressure on the structures. This study was initiated to investigate surface runoff and soil loss as affected by integration of conservation tillage with *fanya juus'* at plot level at Enerata kebele, East Gojjam Zone of Amhara Region. There were two tillage treatments (CT and TT) combined with newly constructed *fanya juus* with four replications. Runoff and soil loss were recorded at 38 rainfall event through three tied trenches within wheat (*triticum vulgare*) and tef (*eragrostis tef*) farm plots. Result showed that average runof f coefficients of 17.72% and 43.96% were recorded due to conservation tillage system from wheat and tef farm plots, respectevly. Thus, runoff coefficient induced 0.54 and 0.18 times reduced in soil loss from wheat and tef plots, respectively. Reduction of runoff volume and soil loss in the conservation tillage systems were attributed to retarded movement of water in the presence of invisible barriers in each furrow that are laid along the contour. The retarded movement of water resulted in increased infiltration and reduced soil loss. Overall, conservation tillage system has a paramount importance in reduction of soil loss while integrated with *fanya juus'* structures in cultivated lands.

Keywords: conservation tillage, fanya juus, runoff, soil loss.

I. Introduction

Soil erosion remains a major threat to soil productivity, agricultural sustainability and rural livelihoods (Tengberg et al., 1997). Especially, it is so severe that there is nowhere in the world where erosion is more destructive to the environment than in the Ethiopian highlands(Dejene,1990; Admasse, 1995). Soil erosion by water represents a major threat to the long-term productivity of agriculture in the Ethiopian highlands (FAO, 1986; 1998). Erkossa et al. (2005 citing SCRP, 1987) repoted that annual soil loss in Ethiopia is estimated at between 1.5 and 3 billion (10^9) tones. Of this, 50% is lost from croplands where it may be as high as 296 t ha^{-1} on steep slopes. Estimates on soil erosion have shown some variabilities. Forexample, 7 t ha^{-1} y^{-1} (Nyssen, 2001) to more than 24 t ha^{-1} y^{-1} (Tamene, 2005); and 80 t ha^{-1} y^{-1} (Tekeste and Paul, 1989) were reported. FAO (1986), also estimated up to 130 t ha^{-1} y^{-1} from cropland and 35 t ha^{-1} y^{-1} averaged over all land use types in the highlands of Ethiopia. Similarly, Hurni (1993) reported from croplands 42 t ha^{-1} yr^{-1}; Herweg and Stillhardt (1999) 59-167 ton/ha, (Girmay *et al.,* 2009) 57 t ha^{-1} yr^{-1}; and (Shiferaw and Holden, 1999)179 t ha^{-1} yr^{-1}, indicated annual losses where soils are conventionally ploughed repeatedly, crop residue is removed completely at harvest leaving no soil cover and aftermath overgrazing of crop fields is common (Oicha 2010; Ayaya, 2011; 2012). Such practices have been intense in the northern and central part of the country, a region with a long history of human settlement where deforestation through land use changes have been practiced for many centuries. In the Ethiopian highlands, agriculture based on cultivation of cereals is thought to have occurred for at least 7000 years (Ehret, 1979).

Cultivation is practiced traditionally through cross plowing using an ard plow (*Maresha*), whose shape and structure have remained unchanged for thousands of years (Goe, 1990; Nyssen et al., 2000; Solomon et al., 2006). This simple wooden ox-drawn plow is well suited for tropical clayey soils because it breaks through hard, dry topsoils. It is also, however, 70 an instrument associated with tillage practices that lead to high rates of on-field erosion, particularly on steep slopes, and the development of a hard, infiltration limiting plow pan (Belay et al., 2013). This traditional maresha cannot permit contour plowing in consecutive tillage operations (Melesse *et al.,* 2008). Cross plowing through *maresha* increases surface runoff as a result of plowing-up and down-the slope.

The existing traditional tillage operation, though varied with crop type, induces erosion due to multiple passes with the maresha, without considering difference in topography, soil type and agro-climatic zone, has become the main factor of land degradation and loss of productivity in the Ethiopian highlands (Hurni and Perich, 1992; Hurni, 1993; Tulema et al., 2008). These repeated operations cause moist soil to move to the surface favoring water loss by evaporation, exposing the

Author α: *University of Gondar, Department of Water Resource and Irrigation Management. e-mail: habtamu.100@gmail.com,*
Author σ: *Wondo Genet College of Forestry and Natural Resources, Shashemene, Ethiopia. e-mail: fantawyimer2003@yahoo.com*
Author ρ: *Addis Ababa University, Faculty of Technology, Department of Civil Engineering, Addis Ababa, Ethiopia.*
e-mail: melesse_tem@yahoo.com

soil to both wind and water erosion (Astatke et al., 2003) and causing structural damage (Melesse et al., 2008). Soil erosion due to high tillage frequency and other soil management problems has seriously affected over 25% of the Ethiopian highlands (Kruger et al., 1996). Such detrimental effect of soil erosion and water stress can be improved to some extent by other management options like conservation tillage integrated with *fanna juu* structures. Small holder farmers have introduced the practice, of course, with the technical support by Development Agents, with the aim to improve soil properties, conserve moisture, reduce runoff and soil loss from their farm lands.

Physical soil conservation structures (SCS) have a paramount importance in decreasing surface runoff. However, in the present study area high rainfall intensity, and increased surface runoff have put extra pressure on the existing soil bund and fannya juu physical structures leading to structural damages, subsequent rill and gulley formations. Thus, it has brought some setbacks to the adoption of soil conservation structures in high rainfall areas 93 such as water loggings, inconveniences to the tradition of cross plowing and concerns about cropland taken up by the structures (Wood, 1990; AHI, 1997; Thomas et al., 1997; Habtamu, 2006).

Conservation tillage system may address the aforementioned problems by reducing surface runoff and improving the infiltration capacity of the soil. According to Melesse (2007; 2009), conservation tillage is a system that conserves water and soil while saving labor and traction needs. This study was undertaken to investigate the effects of conservation tillage integrated with *fanya juus* on runoff and soil loss at plot level in Choke Mountain region, Ethiopia. This type of monitoring is best suited to portraying soil erosion processes and soil disturbances on-site (Corner et al., 1996). On-site soil loss monitoring with runoff plots was found to be a suitable and useful approach as it clearly demonstrates site disturbances and,most importantly, the cause and effect linkages between interventions and impacts (Hartanto et al., 2003).

II. Materials and Methods

a) *Study site*

The study was carried out in Gozamen Woreda, East Gojjam Zone of Amhara National Regional State of Ethiopia. Enirata, the study site, is located 5 km from Debere Markos town in the North West direction (Fig.1). The altitude of the site ranges between 2380 and 2610m above mean sea level. The mean annual total rainfall and temperature are 1300 mm and 15oC, respectively. More than 75% of the annual rain is falling during the months from June to September (*kiremt* rainy season). Nitisols is the dominant soil type in the study area (Belay et al., 2013). These deep, weathered tropical soils are highly susceptible to erosion, and on cultivated lands using traditional methods the rate of soil loss can exceed the rate of soil generation by a factor of 4 to 10 (Hurni, 1988). This has been attributed in part to the prevalence of traditional 116 ox-drawn tillage systems that have been found to promote rapid erosion in the Ethiopian Highlands (Nyssen et al., 2000).

Tillage is exclusively carried out using the traditional tillage implement, *Maresha*. Plowing is done repeatedly before sowing, though, varies with crop types. According to the farmers' response, *teff* fields are plowed after five to seven passes, while other cereal crops required only three to four passes. However, such practice could vary in other parts of the country. Forexample, *teff* is cultivated with intensive seed bed preparations with 3–5 passes in semi-arid (Solomon et al., 2006; Melesse et al., 2008; 2009) and 5–8 passes in humid areas of the country (Fufa et al., 2001) using the ox-driven local maresha, aimed mainly to avoid weeds.

b) *Experimental setup*

Two tillage treatments (conservation tillage and traditional tillage) were cultivated with wheat and teff and replicated four times under eight experimental plots of 5m × 30m treated with *fanya juus* in a Randomized Complete Block Design (RCBD) to measure runoff and sediment loss (Fig 2a). The plots were fenced on the three sides with galvanized iron sheets inserted 20 cm into the ground while the remaining 15cm height above the surface. The fences covered the three sides while *fanya juus* bordered the lower sides of each plot, and then runoff and sediments come into the lower side of collection trench.

All plots were plowed using the traditional tillage implement (*Maresha*) during the first pass. During subsequent passes, two different tillage treatments were applied: conservation tillage (CT) and traditional tillage (TT). Conservation tillage was carried out using a winged sub137 soiler operated along the furrows made by the previous pass of the *Maresha* plow while traditional tillage involved cross plowing using *Maresha* (Melesse, 2007).

The design of trench and field layout were done after determining the surface 139 soil texture (clay loam), slope gradient (7-9%) and the highest rainfall intensity [85mm/day] of the study area from 2001-2010 (DMMS, 2010). The designed trench dimensions are presented in Fig 2b.

c) *Data collection methods*

Three small soil pits were excavated diagnonally at each experimental plot to collect both disturbed and undisturbed core soil samples from depths of 0–10, 10-20 and 20–30cm. For the determination of soil textural fractions and soil organic matter content, samples were collected from each depth. A total of 144 soil samples (2 treatments*2 crop types*4 replications*3 pits*3 depths) were collected across all experimental plots. Similarly, additional independent undisturbed soil samples with cylindrical cores were taken for the determination of soil dry bulk density. A total of 48 infiltration measurements were taken (3 measurements*2 treatments*2 crop types*4 replicates) using double-ring infiltrometer (Bertrannd, 1965). The inner rings had diameters of 28, 30 and 32 cm and the outer rings 53, 55 and 57 cm. The rings were driven approximately 5 cm into the soil using a metal plate and sledge hammer. Water was filled to 20 cm above the soil surface. The rings were refilled to the 20 cm head level each time when the head approached 5 cm above the soil surface. Changes in water levels were recorded at time increments of 0, 1, 2, 5, 10, 15, 20, 30, 40 and 60 min for calculation of infiltration rate and cumulative infiltration (Fantaw et al., 2008).

Prior to soil physical and chemical analyses, all samples were air-dried at room temperature and passed through a 2 mm soil sieve. Soil textural fractions were determined by the hydrometer method after dispersion with sodium hexametaphosphate solution. SOC was determined according to the Walkley and Black method (Schnitzer, 1982). Soil dry bulk density was calculated by dividing the oven dry mass at 105 ^{0}C by the volume of the core. The data were then grouped and summarized according to the treatments (CT and TT).

From the 38 rainfall events induced runoff and soil losses in the lower part of each plot were also measured. The soil loss was measured both as trapped behind the *fanya juus* carried out by pegs and from the part leaving the experimental plot via trenches. Moreover, a sediment collection trough with three isolated parts (trenches) made of galvanized iron sheet were installed to measure the runoff and sediment leaving the plot. In the first trench most of the bed load trapped, while suspended sediments were obtained in all trenches. Twenty pipes were attached close to the top of the lower side of the first trench. One of these pipes was connected to the second trench. The second trench would thus take 5% of the volume from the first trench and pass on 10% of its volume to the third trench through one of the ten pipes attached close to the top of its lower side. The third trench thus collected and stored 0.5% of the daily direct runoff. Therefore, total daily runoff was weighted as the summation of the volumes of the three trenches: T1, T2 and T3.

However, total sediment was calculated as the sum of bed load and suspended load from the trenches. Bed load was carried out by depth measurements at four corners of the trenches and one at the center. Subsequently, the wetted bed load was air dried and weighted. One liter water sample was collected from all trenches for determination of suspended sediment concentration. The sampled water was analyzed using the filtration technique as shown Fig 3. All trenches were cleaned after taking the necessary measurements and made ready for subsequent measurements. Moreover, experimental plots were inspected after every rainfall event for any sign of failure. Statistical differences were tested using two-way analysis of variance (ANOVA) following the general linear model (GLM) procedure of SAS version 9.2. Tukey's honest significance difference (HSD) test was used for mean separation when the analysis of variance showed statistically significant differences ($p < 0.05$).

III. Results and Discussion

a) Soil properties

Excetpt the overall mean bulk density, other soil properties in this study (particle size distribution of sand, silt and clay) and soil organic matter didn't show any significant variations ($p>0.05$, Table 1) with tillage systems. The bulk density under the CT was found to be relatively lower attributed to the slightly higher SOM. Soil organic matter plays a significant role, no matter how big or small the variation is, in improving the soil bulk density.

Mean soil dry bulk density (Bd) under the traditional and conservation tillage systems were significantly different ($p=0.05$) and increased with depth (Table 1). Both the overall and top surface Bd were found to be lower (0.93g cm^{-3}) in soil under the conservation tillage than in the traditional tillage. The lower Bd in the surface soil could be attributed to the relatively higher soil organic matter contents, though not varied significantly across the treatments. Besides the relatively higher SOM contents, the lower over all mean Bd in soil under CT might be related to deep plowing effects which has disrupted the plow plan (Melesse *et al.*, 2008).

b) Water infiltration

Infiltration rate and cumulative infiltration values are presented in Table 2. Results showed that both the rate and cumulative infiltrations significantly ($p=0.01$) varied with respect to tillage systems. Both the infiltration rate and cumulative infiltration values were higher in the conservation tillage system as compared to the traditional tillage system (Table 204 2, Fig. 4). The lower infiltration rate in traditional tillage system may be attributed to the cultivation practice which shears and pulverizes the soil, reduces the macro-pore space and produces a discontinuity in pore space between the cultivated surface and the subsurface layer of the soil (Abdul-Megid et al., 1987; Broersma *et al.,* 1995; Fantaw *et al.,* 2008; Thierfelder and Wall, 2009).

c) Runoff

A significant difference in surface runoff was observed between the two tillage systems under the wheat farm but not in *teff* farm plots. This was due to effects of surface soil compaction resulting from animal trampling during broadcasting of *teff* seeds meant for firming seedbed for improved establishment of the small seeded crop. The effect of animal trampling during sowing of *teff* on the reduction of water infiltration into the soil and increased surface runoff has been documented (Liisa, *et al*, 2004). The highest runoff depth under the traditional tillage was recorded on 27th August, 2010 which resulted in a 23.15mm runoff depth (out of 43.2mm rainfall), which was 54% more than the runoff under the conservation tillage system (Fig 5a). During the study period a total of 153.40 and 79.48mm of total runoff (out of 343.67mm total rainfall) has been recorded in the traditional tillage and conservation tillage systems, respectively. As both treatment plots were under similar conditions with soil type, slope and rainfall distribution, the difference in the depth of runoff generated was mainly attributed to the treatments used. Traditionally, tillage was carried out through cross ploughing of the up and down farming system that was noticeable for the highest runoff generated. The average soil depth of plowing with traditional tillage was 0.57 times lower than that of the corresponding tillage treatment. Repeated tillage at such shallow depth likely produces plow pans as has been found elsewhere in Ethiopia (Melesse *et al.,* 2008). Since the soil bulk density 227 (Table 1) was higher in the traditional ploughed plots, infiltration into the soil was not fast, which was further accelerated by the maximum runoff produced (Nyssen *et al.,* 2000).

On the other hand, average runoff coefficients of 33.5% and 17.7% were recorded in wheat farm plots under the traditional and conservation tillage treatments, respectively. This implied that the rest percentage of the rain was either infiltrated into the soil or lost as evaporation from depression storages or intercepted by plant leaf. The corresponding average runoff coefficient in *teff* farm plots under the traditional and conservation tillages were 50.07% and 43.96%, respectively. The average runoff coefficient was reduced by more than 50% due to the conservation tillage system as compared to the traditional ploughing on wheat farm plot.

The overall results of the present study showed reduced runoff depth and thereby reduced runoff coefficient in the conservation tillage systems compared to the traditional cultivation. Similar study conducted in Spain (De Alba *et al*., 2001) showed a 40% reduction in runoff volume due reduced tillage compared to traditional cultivation. Bonari *et al.* (1995) also reported a 55% reduction in runoff volume when compared to the traditional tillage on a clay soil.

d) Soil loss

Mean soil loss values were found to be significantly different with respect to the tillage systems. The highest sediment yield (bed load plus suspended sediment) from the isolated trenches was recorded in both treatments during the highest runoff periods. The overall result showed that bed load sediment yield was reduced by 47% and 18.42% under conservation tillage as compare to traditional tillage system on wheat and *teff* farm plots, respectively. Similarly, the overall result showed that suspended sediment in conservation tillage was 0.56 and 0.14 times lower than the traditional tillage system on wheat and teff farm plots, respectively.

The total sediment yield (TSY) was higher in the traditional ploughing as compared to conservation system and with a significant treatment effect (Fig. 7). On August 27 the highest daily TSY was recorded in the traditional tillage system which was 1735.21kg from a runoff event with a volume of 231.5m^3 per ha. On this event, the total sediment yield in the conservation tillage treatment was reduced by 57% (Fig. 6).

Unlike wheat fields, *teff* fields showed no significant difference in treatment effects on total sediment yield. This could be due to soil compaction from animal trampling during sowing of *teff* that could undermine treatment effects as compared to wheat farm plot. However, differences in total sediment yield due to tillage treatments were clearly noticeable at higher rainfall depth as observed in Fig 7.

Generally, sediment yield increase as runoff volume increases in both treatment plots throughout the study period. This trend was emanated from the rainfall amount and intensity, which detaches the soil aggregates and transport it easily by sheet erosion (Abiye *et al.,* 2002). Besides, contour ploughing retards the velocity of the water flowing and transported soil materials to the lower part of the plots. So, sediment yield was less in conservation tillage as compared to the traditional tillage system.

IV. Conclusions

In this study, integration of conservation tillage with *fanya juu* showed a significant reduction in soil erosion. This was due to reduction in runoff volume attributed to retarded movement of water in the presence of invisible barriers at each furrow laid along the contour. The retarded movement of water has increased infiltration and reduced soil loss. Enhancing the performance and adoption of soil conservation structure through the integration of conservation tillage systems will have a long term impact on reducing soil erosion and combating land degradation in the highlands of Ethiopia.

V. Acknowledgment

The study has been carried out as a project within a larger research program called "In search of sustainable catchments and basin-wide solidarities in the Blue Nile River Basin", which was funded by the Foundation for the Advancement of Tropical Research (WOTRO) of the Netherlands Organization for Scientific Research (NWO), UNESCO-IHE, Delft, the Netherlands and Addis Ababa University, Ethiopia.

References Références Referencias

1. Abdul-Megid, A.H., Schuman, G.E. and Hart, R.H., 1987. Soil bulk density and water infiltration as affected by grazing systems. Journal of Range Management 40, 307 309.
2. Abiye, A., Jabbar, M., Mohamed-Saleem, M.A., Erkossa, T., 2002. Development and testing of low cost animal drawn minimum tillage implements: experience on Vertisols in Ethiopia. Agric. Mechanization Asia Africa Latin America 33, 290-302.
3. Admassie, Y. (1995) Twenty Years to Nowhere. Property Rights, Land Management and Conservation in Ethiopia. PhD thesis, Uppsala University, Sweden.
4. AHI, 1997. The African Highlands Initiative: Cultivating the future. Nairobi, Kenya. 17 p. Araya, T, W. M. Cornelis, J. Nyssen, B. Govaerts, H. Bauer, Tewodros Gebreegziabher, Tigist Oicha, D. Raes, K. D. Sayre, Mi t iku Haile & J. Deckers. (2011), Effects of conservation agriculture on runoff, soil loss and crop yield under rainfed conditions in Tigray, Northern Ethiopia. Soil Use and Management 27, 404–414.
5. Araya T., Wim M. Cornelis, Jan Nyssen, Bram Govaerts, Fekadu Getnet, Hans Bauer, Kassa Amare, Dirk Raes, Mitiku Haile, Jozef Deckers. (2012) Medium-term effects of conservation agriculture based cropping systems for sustainable soil and water management and crop productivity in the Ethiopian Highlands. Field Crops Research 132, 53–62.
6. Astatke A., Jabbar M. and Tanner D. 2003. Participatory conservation tillage research: an experience with minimum tillage on an Ethiopian highland Vertisol. Agriculture Ecosystem & Environment 95, 401- 415.
7. Belay, S., Benjamin F. and Mutlu O., 2013. Agroecosystem Analysis of the Choke Mountain Watersheds, Ethiopia. Journal of Sustainability 5, 592-616.
8. Bertrannd, A.R., 1965. Rate of water intake in the field. In: Black, C.A. (Ed.), Methods of Soil Analysis, Part I. American Society of Agronomy, Madison, WI, pp. 197–209.
9. Bonari, E., Mazzonzini, M., Peruzzi, A., and Ginanni, M., 1995. Soil erosion and nitrogen loss as affected by different tillage systems used for durum wheat cultivated in a hilly clayey soil. EC-Workshop II Experience with the applicability of no-tillage crop production in the West-European countries, Silsoe, May 15–17, 1995, pp.105–121.
10. Broersma, K., Robertson, J.A., and Chanasyk, D.S., 1995. effects of different cropping systems on soil water properties of a Boralf soil. Communication Soil Society 26,1795-1811.
11. Corner, R.A., Bassman, J.H., Moore, B.C., 1996. Monitoring timber harvest impacts on stream sedimentation: instream vs. upslope methods. Western J. Appl. For. 11 (1), 25–32.
12. DMMS (Debre Markos Meteorological Station). 2010. Meteorological data report from the Year 2001-2010. Meteorological Station at Debre-Markos, Ethiopia. (Unpublished Report).
13. De Alba, S., Lacasta, C., Benito, G., and Perez-Gonzalez, A., 2001. Influence of soil management on water erosion in a Mediterranean semiarid environment in Central Spain. In: World Congress on Conservation Agriculture, Madrid, Spain, pp. 158-165.
14. Dejene, A. (1990) Environment, Famine, and Politics in Ethiopia: A view from the village. Lynne Rienner Publishers, Inc.
15. Douglas, C.L., King, K.A., and Zuzel, J.F. 1998. Nitrogen and Phosphorus in the surface runoff and sediment from a wheat-pea Rotation in northern Oregon. Journal of Environmental quality, 27,1170-1177.
16. Ehret, C., 1979. On the antiquity of agriculture in Ethiopia. J. Afr.Hist. 2, 161–177.
17. Erkossa T., Stahr K. & Gaiser T., 2005. Effect of different methods of land preparation on runoff, soil and nutrient losses from a Vertisol in the Ethiopian highlands. Soil Use and Management 21, 253–259.
18. FAO, 1986. Ethiopian highland reclamation study: Ethiopia, Final Report, FAO, Rome, Italy.
19. FAO, 1998. Conventional tilling severely erodes the soil. New concepts for soil conservation required. Press release. Viewed 6/9: http://www.fao.org /waicent/ois/press_ne/presseng/1998/pren9842.htm
20. Fantaw, Y., Messing, I., Ledin, S, and Abdu, A., 2008. Effects of different land use types on infiltration capacity in a catchment in the high lands of Ethiopia. Soil Use and Management 24, 344-349.
21. Fufa, H., Tesfa, B., Hailu, T., Kibebew, A., Tiruneh, K., Aberra, D., Seyfu, K., 2001. Agronomy research in Tef. In: Hailu, T., Getachew, B., Mark, S. (Eds.), Narrowing the Rift. Tef Research and Development. Proceedings of the International Workshop on Tef Genetics and Improvement, Debre Zeit, Ethiopia, 16–19 October 2000, pp. 167–176.
22. Goe, M.R., 1990. Tillage with the traditional maresha in Ethiopian highlands. Tools and Tillage 6 (3), 127–156.
23. Girmay, G, Singh, BR, Nyssen, J and Borrose, T. 2009. Runoff and sediment-associated nutrient losses under different land uses in Tigray, Northern Ethiopia. Journal of Hydrology 376, 70-80.
24. Habtamu, E. 2006. Adoption of Physical Soil and Water Conservation Structures; MSc thesis, Addis Ababa University, Ethiopia, pp 65–66.

25. Hartanto, H., Prabhu, R., Widayat, A.S.E., Asdak, C., 2003. Factors affecting runoff and soil erosion: plot-level soil loss monitoring for assessing sustainability of forest management. Forest Ecology and Management 180, 361–374.
26. Herweg, K., and Stillhardt, B., 1999. The variability of soil erosion in the Highlands of Ethiopia and Eritrea. Research Report 42. Centre for Development and Environment. University of Berne.
27. Hurni, H., 1988. Degradation and conservation of the resources in the Ethiopian highlands. Mountain Research and Development 8, 123–130.
28. Hurni, H., 1993. Land degradation, famines and resource scenarios in Ethiopia. In: Pimentel, D. world soil erosion and conservation. Cambridge university press. Cambridge, pp. 27– 62.
29. Hurni, H., Perich, I., 1992. Towards a Tigray regional environmental and economic strategy. Development and Environment Reports No. 6. Group for Development and Environment (GDE). Institute of Geography. University of Berne, Switzerland.
30. Kruger H Berhanu F Yohannes G & Kefeni K 1996. Creating an inventory of indigenous soil and water conservation measures in Ethiopia. In: Sustaining the soil: indigenous soil and water conservation in Africa, eds C Reij I Scoones & C Toulmin, International Institute for Environment and Development Earthscan UK.
31. Liisa, P., Rainer, H and Markku, Y., 2004. Effects of trampling by cattle on the hydraulic and mechanical properties of soil. Soil and Tillage Research 82, 99-108.
32. Melesse, T., 2007. Conservation Tillage Systems and Water Productivity Implications for Smallholder Farmers in Semi-arid Ethiopia. PhD Thesis. Taylor & Francis/Balkema, Leiden, the Netherlands, pp. 9-16
33. Melesse, T., Rockstrom, J., Savenije, H.H.G., Hoogmoed, W.B., and Alemu, D., 2008. Determinants of tillage frequency among smallholder farmers in two semi-arid areas in Ethiopia. University Press, Cambridge. Physics and Chemistry of the Earth. 33, 183–191.
34. Melesse, T., Hoogmoed, W., Rockström, J., and Savenije, H., 2009. Conservation Tillage Implements for Smallholder farmers in Semi-arid Ethiopia. Soil and Tillage Research 104, 185–191.
35. Nyssen, J., Poesen, J. Mitiku, H., Moeyesons, J., and Deckers, J., 2000. Tillage erosion by the traditional plough of the Ethiopian Highlands. Soil and Tillage Research 57, 115-127.
36. Nyssen, J. 2001. Erosion processes and soil conservation in a tropical mountain catchment under threat of anthropogenic desertification: a case study from Northern Ethiopia, Ph.D. thesis, Katholieke University, Leuven, Belgium.
37. Oicha Tigist, Cornelis, Wim M., Verplancke Hubert , Nyssen Jan , Govaerts Bram , Behailu Mintesinot, Haile Mitiku , Deckers Jozef. 2010. Short-term effects of conservation agriculture on Vertisols under tef (Eragrostis tef (Zucc.) Trotter) in the northern Ethiopian highlands. Soil & Tillage Research 106, 294–302.
38. Schnitzer, M., 1982. Total carbon, organic matter, and carbon. In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), Methods of Soil Analysis. Part 2, Agronomy Monograph, vol. 9, 2nd ed. American Society of Agronomy, Madison, WI, pp. 539–577.
39. SCRP (Soil Conservation Research Project) 1987. Soil conservation progress report. Ministry of Agriculture, PO Box 62347, Addis Ababa Ethiopia. Shiferaw, B and Holden, S. 1999. Soil Erosion and Smallholders' Conservation Decisions in the Highlands of Ethiopia. World Development 27(4), 739-752.
40. Solomon, G., Mouazen, A., Van Brussel, H., Ramon, H., Nyssen, J., Verplancke, H., Mintesinot, B., Deckers, J., De Baerdemaeker, J., 2006. Animal drawn tillage, the Ethiopian ard plough, maresha: a review. Soil Tillage Res. 89, 129–143.
41. Tamene, L. 2005. Reservoir siltation in the dry lands of northern Ethiopia: causes, source areas and management options, Ph.D. thesis, University of Bonn, Bonn, Germany.
42. Tekeste, G., and Paul, D. S., Soil and water conservation in Tigray, Ethiopia. Report of a Consultancy Visit to Tigray, University of Wageningen,Wageningen, The Netherlands,
43. Tengberg, A., Stocking, M.A., & DaVeiga, M., (1997). The impact of erosion on the productivity of a Ferralsol and a Cambisol in Santa Catarina, southern Brazil. Soil Use and Management 13, 90-96.
44. Thierfelder, C., and Wall, P.C., 2009. Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. Soil and Tillage Research 105, 217–227.
45. Thomas, D.B., Erikson, A., Grunder, M., and Mburu, J., 1997. Soil and water conservation Manual for Kenya. Soil and Water Conservation Branch, Ministry of Agriculture, Livestock Development and Marketing. Republic of Kenya. Nairobi, pp 49- 55.
46. Tulema Balesh, Aune Jens B., Johnsen Fred H., Vanlauwe Bernard. 2008. The prospects of reduced tillage in tef (Eragrostis tef Zucca) in Gare Arera, West Shawa Zone of Oromiya, Ethiopia. Soil & Tillage Research 99, 58–65.
47. Wood, A., 1990. Natural resource management and rural development in Ethiopia. In: Pausewang, S., Cheru, F., Bruene, S., Chole, E., (Eds.), Ethiopia: Rural Development Options. Zed Books, London, pp 58.

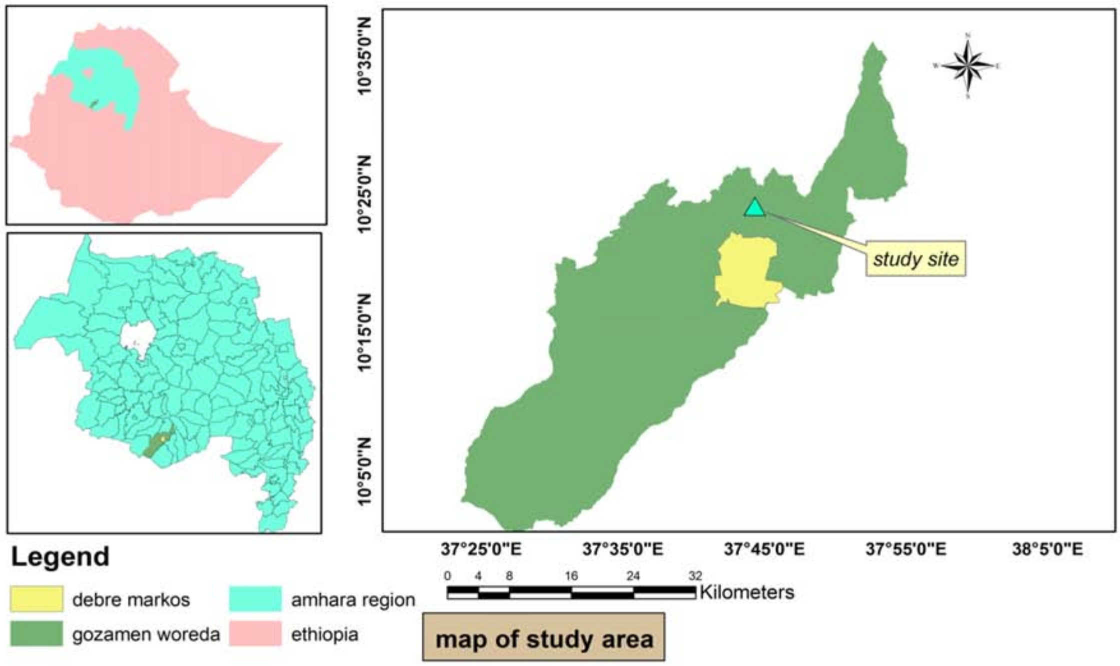

Figure 1 : Location map of the study area

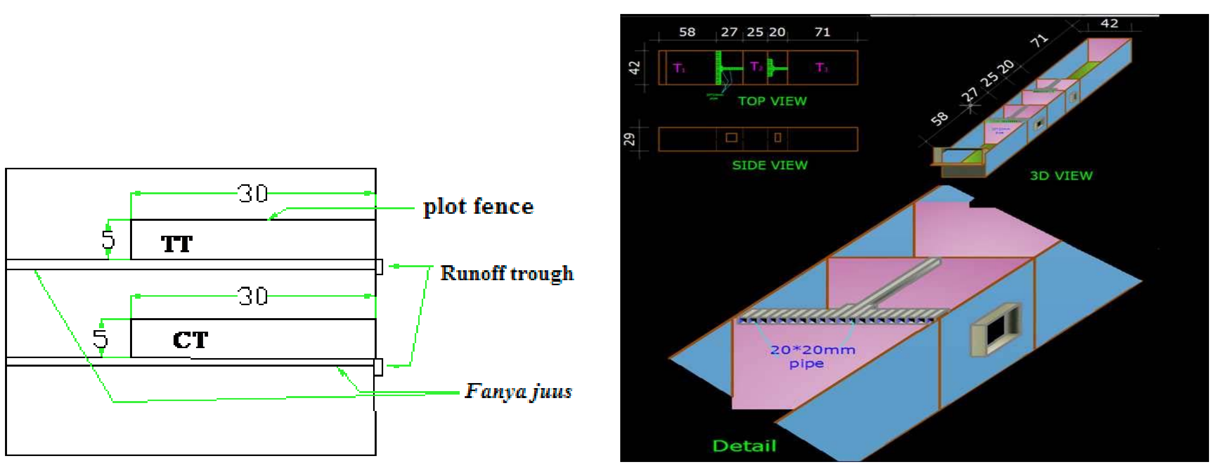

Figure 2 : Layout of a single replication (2a) and design of runoff and sediment collection trench (2b) collection trench

Global Journal of Science Frontier Research (D) Volume XIV Issue VII Version I Year 2014

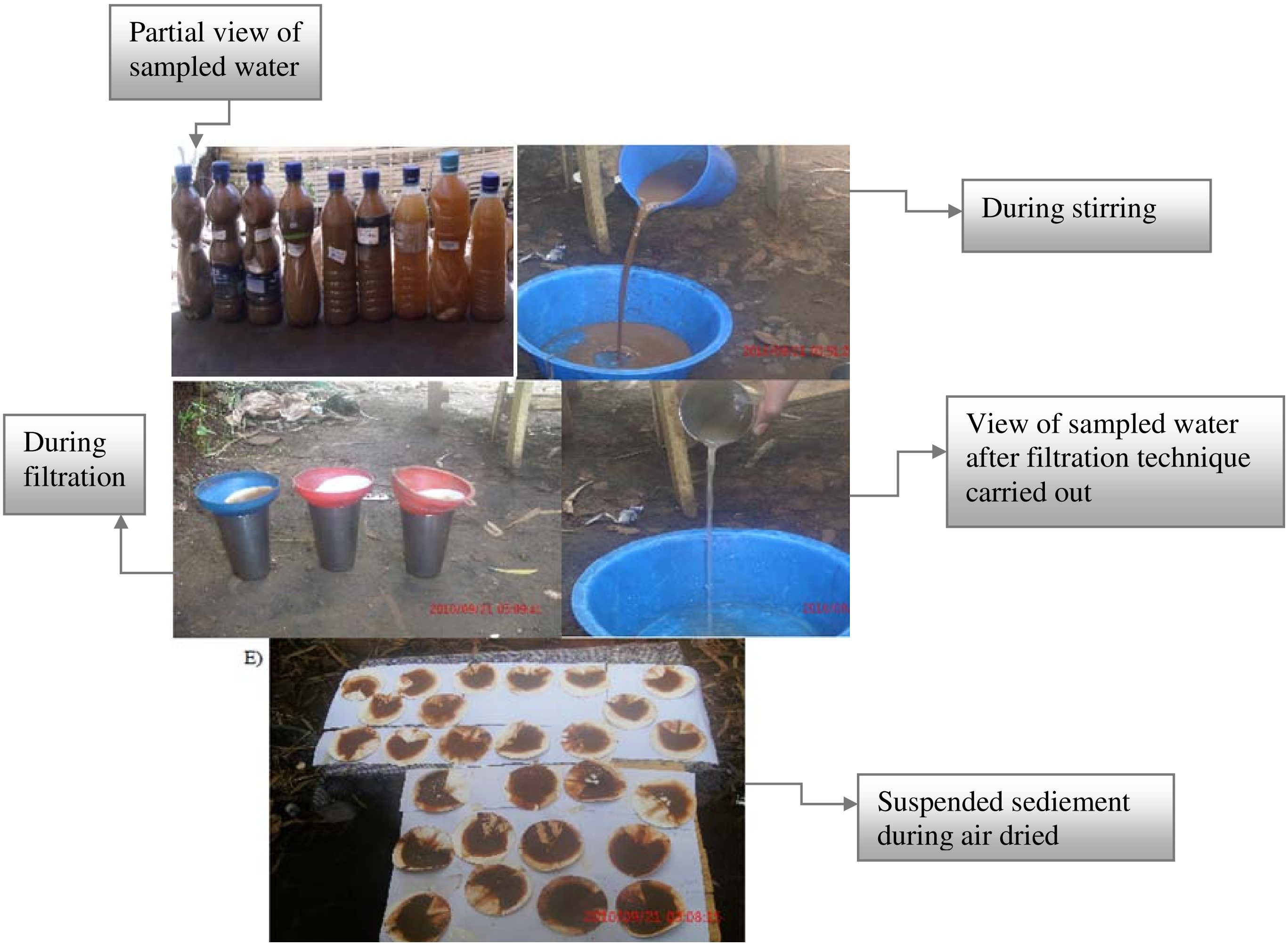

Figure 3 : Determination of suspended sediment

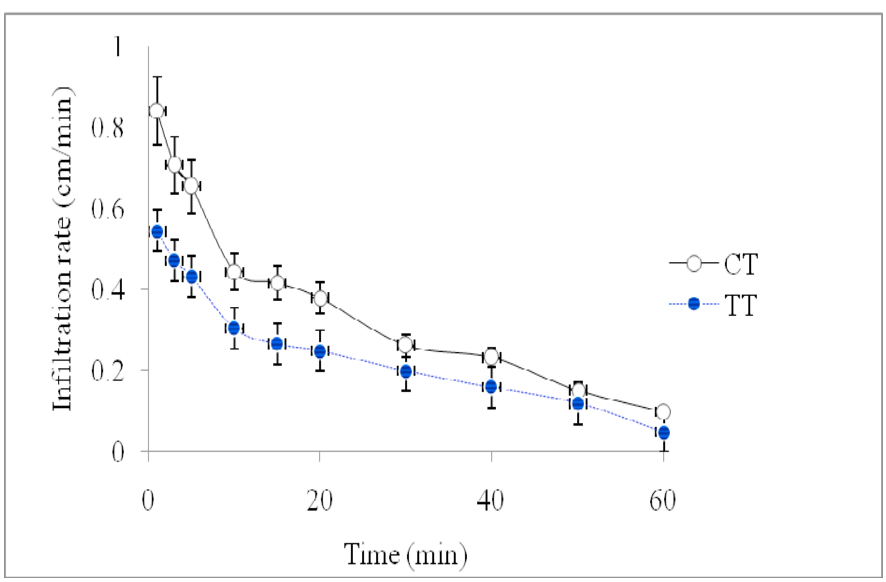

Figure 4 : Infiltration rate with tillage methods (CT= means conservation tillage using winged sub-soiler while TT is traditional tillage using *Maresha*) in the study area)

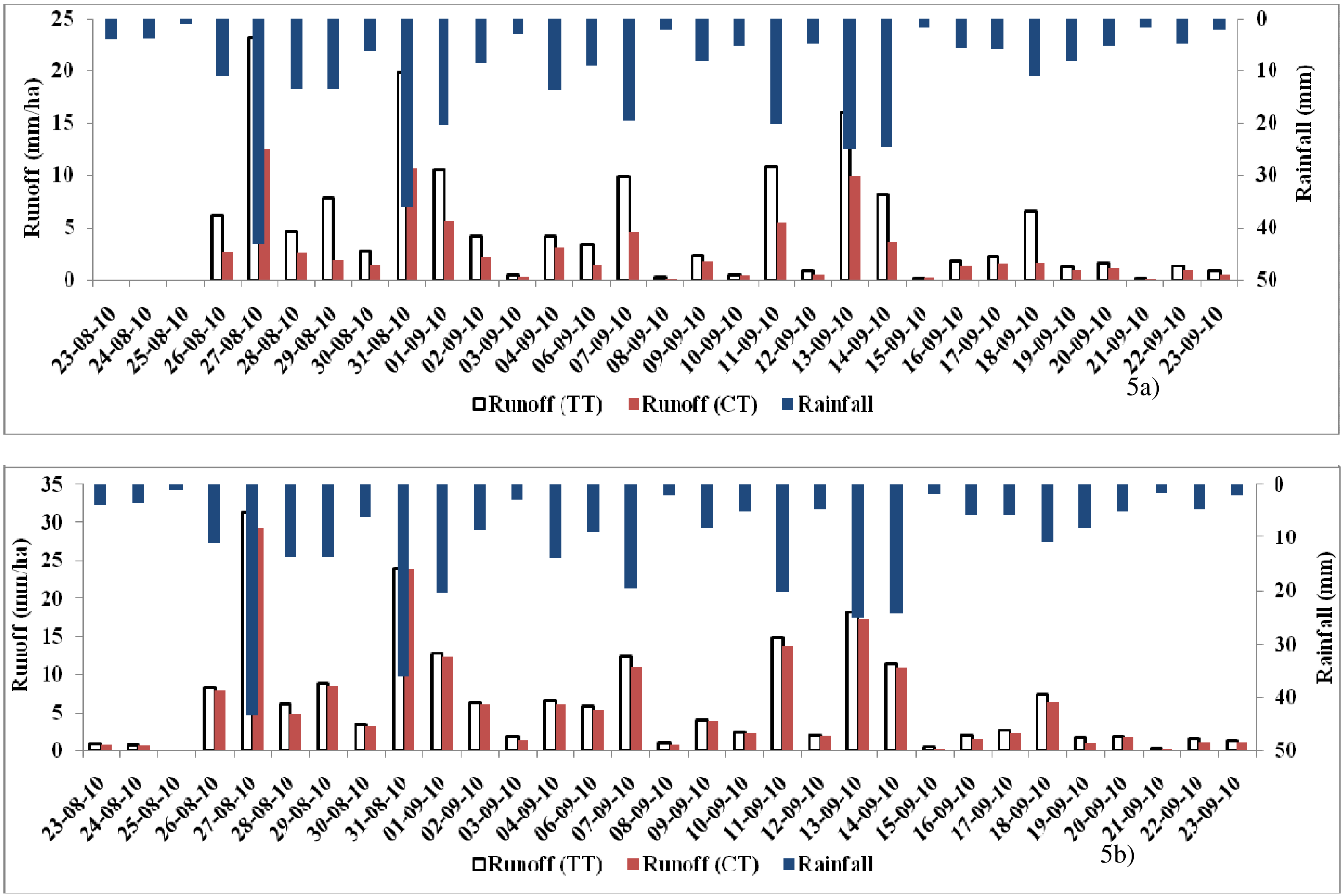

Figure 5 : Time series of measured daily rainfall and runoff results under wheat (5a) and tef (5b) crop respectively at experimental plot

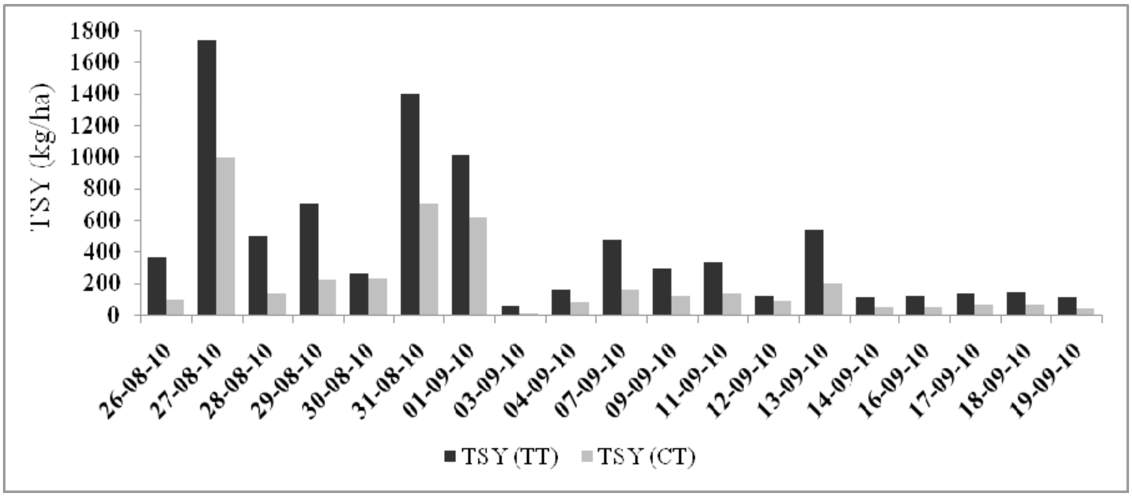

Figure 6 : Daily total sediment yields from the tradition and conservation tillage treatments on wheat farm plots

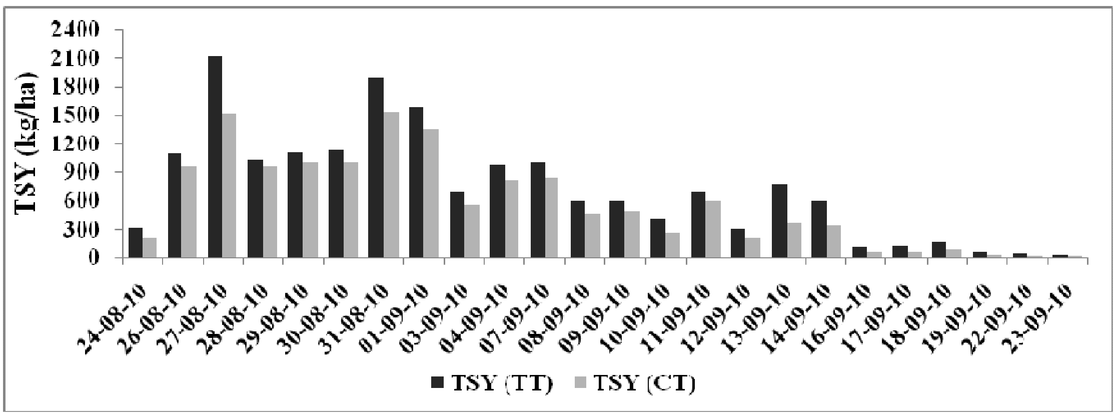

Figure 7 : Daily total sediment yield from the tradition and conservation tillage treatments *tef* farm plots

Table 1 : Summary of ANOVA results for particle size distribution (%), bulk density (Bd, g cm^{-3}), and soil organic matter (SOM, %) in relation to tillage systems and soil depths

Variables	Soil depth (cm)	Tillage system TT	CT
Sand	0 – 10	45.74±0.47	45.76±0.48
	10 – 20	50.17 ±0.93	50.00±0.91
	20 – 30	48.16 ±0.41	48.20±0.39
	Overall	48.02 ±0.6^{a}	48.02±0.59^{a}
Silt	0 – 10	32.16±0.70	32.10±0.71
	10 – 20	24.32±0.41	24.26±0.39
	20 – 30	16.11±0.43	16.18±0.41
	Overall	24.20±0.51^{a}	24.18±0.50^{a}
Clay	0 – 10	32.16±0.70	22.01±0.91
	10 – 20	24.32±0.41	25.75±0.81
	20 – 30	16.11±0.43	36.54±0.28
	Overall	24.20±0.51^{a}	28.10±0.66^{a}
Bd	0 – 10	0.98±0.005	0.93±0.005
	10 – 20	1.11±0.006	1.03±0.005

	20 – 30	1.13±0.005	1.12±0.003
	Overall	1.07±0.005[a]	1.03±0.043[b]
SOM	0 – 10	2.49±0.005	2.51±0.004
	10 – 20	2.11±0.005	2.11±0.006
	20 – 30	1.76±0.009	1.77±0.007
	Overall	2.12±0.006[a]	2.13±0.005[a]

Mean±SE followed by the same letter across the row are not significant (p=0.05) with respect to soil depths

Table 2 : Water infiltration rate (cm/min) and cumulative infiltration (cm) of soils as affected by tillage treatments integrated with graded *fanya juus* with time serious (mean± SE)

Time (min)	Infiltration rate (cm/min)		Cumulative infiltration (cm)	
	CT	TT	CT	TT
1	0.84±0.005[a]	0.55±0.006[b]	0.84±0.004[a]	0.55±0.006[b]
3	0.71±0.005[a]	0.47±0.005[b]	1.55±0.006[a]	1.05±0.006[b]
6	0.10±0.001[a]	0.05±0.004[b]	4.23±0.006[a]	2.72±0.006[b]
Over all	0.42±0.004[a]	0.28±0.004[b]	2.91±0.006[a]	1.935±0.006[b]

Mean±SE followed by the different letter across the row are significant (p=0.01) at each time series with respect to infiltration rate and cumulative infiltration

.

This page is intentionally left blank