

# POTENTIAL EFFECTS OF VINASSE AS A SOIL AMENDMENT TO CONTROL RUNOFF AND SOIL LOSS

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## **Abstract**

Application of organic materials are well known as environmental practices in soil restoration, preserving soil organic matter and recovering degraded soils of arid and semiarid lands. So, the present research focused on evaluating the effectiveness of vinasse, a byproduct mainly of the sugar-ethanol industry, on soil conservation under simulated rainfall. Vinasse can be recycled as a soil amendment due to its organic matter. Accordingly, the laboratory experiments were conducted by using 0.25 m<sup>2</sup>-experimental plots at 20% slope and rainfall intensity of 72 mm h<sup>-1</sup> with 0.5 h duration. The effect of three rates of vinasse at 0.5, 1, and 1.5 l m<sup>-2</sup> was investigated on runoff and soil loss control. Laboratory results indicated that vinasse at different levels could nonsignificantly (P>0.05) decrease the runoff amount and soil loss rate in the study plots compared to untreated plots except 1.5 l m<sup>-2</sup> which nonsignificantly increased the runoff volume. Also, the results indicated that the soil loss amount at the vinasse application rate of 1 l m<sup>-2</sup> was the least. The average amounts of minimum runoff volume and soil loss were about 3985 ml and 46 g for the study plot at 1 l m<sup>-2</sup> level of vinasse application.

## **1 Introduction**

Soil erosion is an environmental concern resulting in increased sedimentation, turbidity and levels of pollutants in adjacent water bodies (Ebisemiju, 1990; Pieri et al. 2007; Girmay et al., 2009; Bhattarai et al., 2011, Bakr et al., 2012). According to the Forest, Rangeland and

1 Watershed Management Organization of Iran, about 150 M US dollars are annually spent on  
2 the watershed management projects implemented to prevent or to alleviate part of soil erosion  
3 related problems in the country (Sadeghi et al., 2011). It led to erosion control technologies  
4 receiving a great deal of attention to reduce soil erosion. Accordingly, soil erosion control has  
5 principal importance in soil management and conservation in developing countries like Iran  
6 (Newson, 2002; Haghjou et al., 2014). Besides that, soil management is important to crop  
7 productivity, environmental sustainability and consequently human welfare.

8 Covering the bare soil with an appropriate material is one of the soil management  
9 practices, which increases water infiltration and surface storage by enhancing the soil  
10 structure and porosity. The layer of residues protects the soil against erosion, inhibits weed  
11 germination, improves water retention, ameliorates physical and biological soil properties,  
12 and is a source of plant nutrients (Sheoran et al., 2010; Araujo-Junior et al., 2013; Prado et al.,  
13 2013). In addition, industrial processing of sugar cane to produce sugar and alcohol also  
14 generates residues, such as filter cake and vinasse, which have a great potential for use in  
15 agriculture as soil improvers and fertilizers (Prado et al., 2013). Meanwhile, to prevent soil  
16 loss many organic soil improvers are mainly used (Tejada et al., 2009; Rigane and Medhioub,  
17 2011). Additionally, according to Tejada et al. (2006a, 2006b), the general increasing of  
18 biomass C in a soil can be associated to the constructive impact of organic materials on the  
19 soil physical properties. The application of animal, industrial and municipal wastes is also  
20 prevalent throughout the world as they can be an excellent source for nutrient and organic  
21 matter (Bhattarai et al., 2011). Several studies have evaluated the effects of composted  
22 organic wastes such as animal manure and sewage sludge compost on soil properties, quality  
23 and productivity, dissolved organic carbon and nitrate leaching (e.g. Adler and Sikora, 2005;  
24 Margesin et al., 2006; Bastida et al., 2007; Karami et al., 2012; Zornoza et al., 2013;  
25 Eykelbosh et al., 2015), but there are relatively few studies (e.g. Tejada and Gonzalez, 2006b;  
26 Tejada et al., 2007; Tejada and Gonzalez, 2008; Gholami et al., 2013; Cerdà et al., 2014a,b;  
27 Sadeghi et al., 2015a,b) on evaluating of the effect of organic waste and residues on runoff  
28 and soil loss control.

29 Application of organic amendment and mulches has already been proved as a method of  
30 improving soil physical properties leading to affect runoff and soil erosion (Albaladejo et al.,  
31 2000; Cerdà and Doerr, 2008; Cerdà et al., 2014a,b). Moreover, organic amendments are  
32 increasingly being examined for their potential use in preventing soil losses (Tejada and  
33 Gonzalez, 2008). There are a variety of organic amendments for soil management and

1 conservation, with different performance and mechanisms. In spite of that, different organic  
2 amendments, viz. cotton gin crushed compost and poultry manure, beet vinasse, sewage  
3 sludge, organic urban solid refuse, sheep manure, cow manure, rice husk, finely chopped  
4 reeds, wheat straw, licorice (root) dregs (Agassi et al., 1998; Albaladej et al., 2000; Ojeda et  
5 al., 2003; Tejada and Gonzalez, 2006b; Tejada et al., 2007; Tejada and Gonzalez, 2008;  
6 Nicolás et al., 2012; Karami et al., 2012) have been used for soil conservation in agricultural  
7 and forestry soils, commonly.

8 Recently, with the advances in industrial sector, significant amount of wastes and residual  
9 can be produced which create another source of load on the environment. Also, the high cost  
10 of fertilizers and concerns about environmental protection have been great incentives to study  
11 the recycling of the large quantities of organic residues produced as byproducts of the sugar  
12 and alcohol agro-industries in agriculture (Prado et al., 2013). For instance, the production of  
13 one liter of ethanol generate on average between 10-15 liters of vinasse. Vinasse is classified  
14 as a class II residue, not inert but not dangerous. **Vinasse, like other organic fertilizers has**  
15 **high organic matter, N and K contents (Madejón et al., 2001)**, which promotes nutrient  
16 recycling in ecosystems, and causes less environmental impacts during production. Sugarcane  
17 industries generate large quantities of waste generally known as vinasses, stillages or  
18 molasses spent wash during the process of ethanol production (Espanã-Gamboa et al., 2011).  
19 Vinasse is an important byproduct of ethanol and sugarcane industries, intensively applied to  
20 soils in Brazil as liquid fertilizer (Ribeiro et al., 2013). **However, the direct application of**  
21 **vinasse is constrained by its high salinity and high density.** These issues can be mitigated  
22 through mixing the vinasse with other solid wastes. The environmental damage caused by  
23 discarding vinasse into the soil or running waters was an incentive to studies aiming to find  
24 alternative, economic applications for this residue. Results from such studies indicate that  
25 vinasse contributes to improvements in soil quality and agricultural productivity, **if it would**  
26 **be properly used** (Prado et al., 2013).

27 Though, many studies have been performed to identify the effects of vinasse application on  
28 growth, development and production of sugarcane and physical properties of soil (e.g. **Tejada**  
29 **et al., 2009; Jiang et al., 2010; Prado et al., 2013; Ribeiro et al., 2013)**, but very limited  
30 studies were taken place to study the effects of application of vinasse on surface runoff and  
31 water soil loss rate. According to previous studies (**Tejada and Gonzalez, 2006a, 2007; Tejada**  
32 **et al., 2006a, 2007)**, the application of beet vinasse had unfavorable impacts on some soil  
33 properties viz. structural stability, bulk density, ESP, microbial biomass, respiration,

1 enzymatic activities. Tejada and Gonzalez (2006b) investigated the relations between soil  
2 erosion and erodibility (K) in a treated soil by cotton gin crushed compost (CC) and beet  
3 vinasse (BV) applied for 5 years on a Typic Xerofluvent. They demonstrated that an increase  
4 in dose of CC applied to the soil caused a decrease in K and soil loss, but when BV was  
5 applied, the soil physical and biological properties were declined. The results revealed that in  
6 the BV-treated soils under a rainfall with 45 min duration and 60 mm h<sup>-1</sup> intensity, the K  
7 factor decreased by 6.4% at the end of the experiment compared to control soil. Madejón et al.  
8 (2001) also investigated the effect of three vinasse composts on crops (corn and sugar beet)  
9 and some chemical properties of a calcareous loamy sand soil. Their results indicated that the  
10 use of compost contributed to enhancing the level of organic matter in agricultural soils in  
11 SW Andalusia, Spain, which was particularly poor in organic matter. Characterization of  
12 vinasses from different feedstock sources by Espanã-Gamboa et al. (2011) showed the most  
13 appropriate treatments for the vinasses soluble solids conditioning. They verified that the  
14 vinasses could be safely used in agriculture without contaminating soil, underground water or  
15 crops, for energy recovery and animal feeding.

16 A review of the literature demonstrated the effectiveness of different organic amendments  
17 on growth, development and production of sugarcane and physical properties of soil as well.  
18 The literature review also clearly verified the variable behavior and effectiveness of different  
19 organic amendment, which necessitates further studies under different conditions and for  
20 other organic amendment. However, there was no comprehensive study on evaluation of the  
21 effect of vinasse amendment on runoff and soil loss control. In recent years, soil erosion has  
22 been extensively studied in laboratory using rainfall simulators. So that, the soil erosion plots  
23 and rainfall simulators are two important research equipments widely employed in erosion  
24 studies, worldwide. They allow producing runoff and occurring soil loss under repeatable and  
25 controlled conditions. In addition, the review of literatures has confirmed that the employ of  
26 different sized plots is practically applicable, logically economic and easily controllable and  
27 repeatable due to which their further utilizations have been advised with particular  
28 considerations (Sadeghi et al., 2012). On the other hand, there is several sugarcane agro-  
29 industry development companies in southwestern of Iran producing huge quantity of vinasse  
30 mainly discharges into adjacent rivers. The present study therefore examines the potential role  
31 of vinasse amendment on runoff and soil loss reduction on a silt loam soil collected from a  
32 summer rangeland, northeastern Iran using a simulated rainfall intensity of 72 mm h<sup>-1</sup> and  
33 slope of 20%.

## 2 MATERIALS AND METHODS

### 2.1 Soil properties

The soil required for the study was provided from upper 30 cm of the soil surface layer from Badranlou area in Northern Khorasan Province, Iran, and transported to the laboratory. The area is mainly under dry land farming system and very prone to soil erosion. The texture of the study soil was silty loam (48% silt, 28% clay and 24% sand). The measured organic matter, pH, electrical conductivity and bulk density of the soil were 0.155%, 8.2, 137.3  $\mu\text{mohs cm}^{-1}$  and  $1.3 \text{ g cm}^{-3}$ , respectively.

### 2.2 Plot preparation

Experimental plots with 0.5 m long, 0.5 m wide, and 0.3 m deep were used for the present study. The soil was then prepared for application and simulated in the plots using previously reported methods (Thompson and Beckmann, 1959; Loch and Donnollan, 1988; Kukal and Sarkar, 2011). The upper 10 cm of the soil was compacted by concrete roller to achieve the desired bulk density of  $1.3 \text{ g cm}^{-3}$  and similar to the field conditions. To establish the filter layer under the experimental soils, three layers of mineral pumice grains with different sizes with total thickness of 17 cm were packed. Based on the annual average soil moisture content, the soil was also treated to produce a moisture content of 35%.

### 2.3 Vinasse characteristics

Vinasse used for the experiment was produced by Research and Training Institute for the Industrial Development of Sugarcane in Khuzestan Province, Iran. The levels of vinasse application (0.5, 1 and  $1.5 \text{ l m}^{-2}$ ) were selected based on information existed for application of vinasse for other purposes and other amendments, avoiding considerable environmental pollution due to high contents of N and K probably leading to high salinity and high density, feasibility of application and accessibility as well (Madejón et al., 2001; Tejada and Gonzalez, 2005, 2006a, 2006b; Tejada et al., 2007, 2009; Jiang et al. 2010; Maldonado et al., 2011). Three levels of 0.5, 1 and  $1.5 \text{ l m}^{-2}$  of vinasse were sprayed on soil surface in three replications and left for 24 h to increase the stability of vinasse layer on the soil surface and mimic the natural conditions.

## 2.4 Laboratory experiments

To evaluate the effectiveness of vinasse for runoff and soil loss control, laboratory experiments were conducted under a rainfall simulator at the Rainfall and Soil Erosion Simulation Laboratory of Faculty of Natural Resources of Tarbiat Modares University, located in Noor Campus, Mazandaran Province, Iran. The rainfall simulator consists of a 4000 L water tank and 27 precalibrated nozzles in three parallel lines designed to simulate raindrops of 1.3 mm average size. The drops fall from a height between 4 and 6 m at the upper and lower parts of the plot, respectively, reaching a  $7 \text{ ms}^{-1}$  speed the study plot (Gholami et al., 2013; Sadeghi et al., 2015a,b). The laboratory experiments were conducted at 20% slopes under simulated rainfall intensity of  $72 \text{ mm h}^{-1}$  with duration of 30 min almost corresponded with natural rainstorms of the study area. The rainfall intensity of  $72 \text{ mm h}^{-1}$  with duration of 30 min were considered corresponded with climatological condition in the origin of the soil obtained through IDF curves analysis for data collected from the nearest synoptic station (Bojnourd, Northern Khorasan Province in Northeast of Iran) with the return period of 50 years. The slope of 20% was selected based on the average slope of the original area where the soil was collected (Hazbavi, 2013; Hazbavi et al., 2013; Sadeghi et al., 2014). A general view of the experimental setup is shown in Fig. 1.

The sediment laden runoff was measured at different time steps of 2 to 5 min for the entire period of the experiments. The samples were then oven dried for 24 h at  $105^\circ\text{C}$  and corresponding sediment concentration and soil loss were determined. Also, the runoff commencement and cessation times were also recorded. The time of runoff commencement and cessation times, and regular measurement of runoff volume were measured by a chronometer and standard gauged cylinders, respectively (Gholami et al., 2013; Sadeghi et al., 2014; Sadeghi et al., 2015a,b, Sadeghi et al., 2016).

## 2.5 Statistical analyses

All analyses were performed on triplicate samples and subjected to analysis of variance (ANOVA). The data were tested for homogeneity of variances at a significance level of  $P < 0.05$  and probability values of less than 0.05 were then considered as statistically significant in one-way ANOVA. Significant means were subjected to analysis by Duncan's multiple range test ( $P < 0.05$ ). The SPSS V.19 software package was used for the statistical analyses.

### 3 RESULTS AND DISCUSSION

#### 3.1 Runoff

The variations of runoff and cumulative runoff volume with rainfall duration for various vinasse application rates are shown in Figs. 2 and 3. As it is seen in Figs. 2 and 3, the maximum and the minimum reduction in runoff generation occurred at 1 and 1.5 l m<sup>-2</sup> levels of vinasse application, respectively.

The maximum and minimum runoff volumes were 21627.16 ml m<sup>-2</sup> at control plot and 11884.040 ml m<sup>-2</sup> at 1 l m<sup>-2</sup> level of vinasse treated plot, respectively (Table 1). The results of the ANOVA test to assess the effect of vinasse on runoff volume under study condition have also been presented in Table 2. The ANOVA results showed that the effect of vinasse on runoff volume was not significant at a confidence level of 95% (P= 0.643), which is consistent with Madejón et al. (2001) who reported that single application of vinasse did not significantly influence runoff and erosion from simulated rainfall. The less runoff in 0.5 and 1 l m<sup>-2</sup> vinasse-treated plots compared to control plot confirmed the previous observations of Bakr et al. (2012) for different soils of Louisiana, Gholami et al. (2013) and Sadeghi et al. (2015a,b) for sandy-loam soil of the Alborz Mountains who reported that the compost/mulch cover led to reduce runoff at plot scale. But more runoff in 1.5 l m<sup>-2</sup> vinasse-treated plots in comparison with control plot verified changing effectiveness of vinasse on runoff control. It is due to water repellency phenomena, probably. The increased use of vinasse may affect water repellency and have the potential to be easily transported in surface runoff at high levels. Agassi et al. (1998) verified that the hydrophobic sound effects, which are common to a range of organic amendments, may decrease the infiltration rate in soil treated with sludge as organic amendment. This result persisted for a long time after the sludge has been used.

The runoff commencement and cessation times under different vinasse treatments are also shown in Fig. 4. The runoff commencement time was recorded at the onset runoff reached plot outlet. As it is seen in Fig. 4, vinasse increased the runoff commencement time about 2.25 times more compared to that reported for untreated plots. This is consistent with previous studies (e.g. Gholami et al., 2013; Sadeghi et al., 2015a) showing that some organic amendments promote runoff commencement time and delaying runoff. Also, vinasse decreased the runoff cessation time almost 0.9 times less compared to that reported for untreated plots. The maximum effectiveness for both variables occurred at 1.5 l m<sup>-2</sup> level of vinasse application.

1 The effect of vinasse on runoff commencement and cessation times under study conditions  
2 was also statistically analyzed by ANOVA whose results have been given in Table 2. The  
3 results clearly showed that the effect of vinasse on runoff commencement and cessation times  
4 were highly significant at a confidence level of >99% ( $P < 0.006$ ).

### 6 3.2 Soil loss

7 The average values of eroded soil under different vinasse treatments under experiment  
8 conditions have been shown in Fig 5. Fig. 6 also shows the cumulative variation of soil loss  
9 under different vinasse treatments. It was observed from the results that the vinasse treatments  
10 decreased soil loss rates during the entire period study except for 10<sup>th</sup> and 25<sup>th</sup> minutes of  
11 record for 0.5 l m<sup>-2</sup> vinasse application. The application rate of 1 l m<sup>-2</sup> performed better than  
12 other two treatments in reducing the amount of eroded soil from the plots. All three vinasse  
13 treatments produced less eroded soil in comparison with control plots.

14 Table 3 contains the specific values of average soil loss for vinasse treatments. The vinasse  
15 treatment at 1 l m<sup>-2</sup> level produced, on average, less eroded soil. The results verified that the  
16 vinasse protected soil aggregates from the direct impact of rain drops and prevented soil  
17 detachment. It also helped to increase surface roughness preventing quick runoff generation.  
18 Tejada and Gonzalez (2006b and 2007) and Tejada et al. (2009) found that adding different  
19 organic wastes increased soil structural stability and decreased soil loss. Tejada et al. (2009)  
20 also reported, in particular, that the fresh beet vinasse application had a negative effect on the  
21 soil physical, chemical and biological properties. They stated that the fresh beet vinasse  
22 increased soil loss and decreased plant cover because of high quantities of monovalent cations  
23 of fresh beet vinasse such as Na<sup>+</sup>. Tejada and Gonzalez (2008) further found that cotton gin  
24 crushed compost (CC) and poultry manure (PM) at the higher dose reduced soil loss under  
25 simulated rain at 140 mm h<sup>-1</sup> by 29.2% and 25%, respectively, compared to the control soil.  
26 All the studied treatments reduced soil loss, especially in the plots treated with the higher  
27 concentration of organic matter. However, the CC treatments were more efficient than the PM  
28 treatments. In soils amended with beet vinasse a degradation of soil structure and increase on  
29 erosion were observed due to the enrichment of the cation exchange capacity by monovalent  
30 cations, such as K (Tejada and Gonzalez, 2006a; Tejada et al., 2007). High saturation of K in  
31 the cation exchange capacity may lead to soil dispersion and, consequently, to soil erosion  
32 and land degradation. In addition, whenever vinasse is applied to silty loam soil, a part of  
33 them fills up the voids of soil, and other part stays on the soil aggregates surface. The effects

1 of vinasse may be temporary, since the organic compounds of vinasse are highly  
2 decompose from vinasse cementing the micro aggregates and favoring the flocculation of  
3 clay fraction (Ribeiro et al., 2013).

4 The results of the ANOVA test to assess the effect of vinasse on soil loss are presented in  
5 Table 4. The results of ANOVA also showed that the effect of vinasse on soil loss was not  
6 significant at confidence level of 95% ( $P=0.506$ ), which agrees with Madejón et al. (2001). It  
7 is reported that depend upon the type, amount, size and dominant components of the added  
8 organic materials, the influence of organic matter on soil loss is different (Tejada and  
9 Gonzalez, 2006b, 2007). For instance, Tejada and Gonzalez (2005) showed that an increase in  
10 electrical conductivity caused by high vinasse application rate adversely affects soil total  
11 porosity, bulk density, and structural stability. Thus, soil physical properties can be influenced  
12 by vinasse application. These changes in soil properties can have a substantial impact on  
13 runoff and soil loss from fields where vinasse has been applied. Tejada et al. (2006) found  
14 that organic amendments improve soil structure because they promote the flocculation of clay  
15 minerals, which is important for soil particle aggregation.

16 The soil texture of the study area i.e. silty loam used in the vinasse application on soil loss  
17 analyses could also justify the hydrologic behavior of the study plots. Because of the limited  
18 number of study locations, it was not possible to identify the effects of textural characteristics  
19 on calculated runoff and soil loss ratios. As Ojeda et al. (2003) noted, the sandy and loam  
20 soils treated by  $10 \text{ t ha}^{-1}$  of dry matter of the sewage sludge differ in their susceptibility to  
21 runoff generation and soil erosion to soil amendments application. So that, for loam soil  
22 erosion increases with runoff. This would suggest that erosion on this type of soil could be  
23 limited by runoff transport.

## 24 25 **4 Conclusions**

26 The results of the study indicated that the single application of vinasse did not significantly  
27 influence on runoff and erosion. The results also revealed that the least amount of runoff and  
28 soil loss produced at  $1 \text{ t m}^{-2}$  of vinasse-treated silt loam soil. Vinasse composts can be then  
29 used as an alternative to mineral fertilizers and reduce soil erosion and water loss. Since the  
30 runoff and soil loss ratios from different plots and even under realities may be different from  
31 those obtained during present study, further researches are needed for better understanding the  
32 potential benefits and limitations of various applications of vinasse for sound management of  
33 water and soil and to allow drawing comprehensive conclusion. More and long term

experiments are also needed for monitoring and evaluating long term effects of vinasse on soil hydrology and erosion processes with particular focus on environmental effects.

## Acknowledgements

The authors are thankful to Professor Hassan Hamdi, the Managing Director of Research and Training Institute for the Industrial Development of Sugarcane in Khuzestan Province, Iran, for providing vinasse amendment.

## References

- Adler, P. R., and Sikora, L. J.: Mesophilic composting of arctic char manure, *Compost Sci Util.*, 13, 34-42, 2005.
- Agassi, M., Kirsten, W. F. A., Looek, A. H., Fine, P.: Percolation and leachate composition in a disturbed soil layer mulched with sewage biosolids, *Soil Till. Res.*, 45, 359-372, 1998.
- Albadejo, J., Castillo, V., Diaz, E.: Soil loss and runoff on semiarid land as amended with urban solid refuse, *Land Degrad. Dev.*, 11, 363-373, 2000.
- Araujo-Junior, C. F., Noedi Rodrigues, B., Dias Chaves, J. C., and Yada Junior, G. M.: Soil physical quality and carbon stocks related to weed control and cover crops in a Brazilian Oxisol, Chapter 8, *Weed and pest control - conventional and new challenges*, ISBN: 978-953-51-0984-6, InTech, DOI: 10.5772/54363. Available from: <http://www.intechopen.com/books/weed-and-pest-control-conventional-and-new-challenges/soil-physical-quality-and-carbon-stocks-related-to-weed-control-and-cover-crops-in-a-brazilian-oxiso>, 181-205, 2013.
- Bakr, N., Weindorf, D. C., Zhu, Y., Arceneaux, A. E. and Selim, H.M.: Evaluation of compost/mulch as highway embankment erosion control in Louisiana at the plot-scale, *J. Hydrol.*, 468-469, 257-267, 2012.
- Bastida, F., Moreno, J. L., Garc'ia, C., and Hern'andez, T.: Addition of urban waste to semiarid degraded soil: long-term effect, *Pedosphere*, 17, 557-567, 2007.
- Bhattarai, R., Kalita, P. K., Yatsu, Sh., Howard, H. R., and Svendsen, N. G.: Evaluation of compost blankets for erosion control from disturbed lands, *J. Environ. Manage.*, 92, 803-812, 2011.
- Cerdà, A., and Doerr, S. H.: The effect of ash and needle cover on surface runoff and erosion in the immediate post-fire period, *Catena*, 74, 256-263, 2008.
- Cerdà, A., Giménez-Morera, A., Jordán, A., Pereira, P., Novara, A., and García-Orenes, F.: The use of straw mulch as a strategy to prevent extreme soil erosion rates in citrus orchard. A

1 Rainfall simulation approach, EGU General Assembly 2014, 27 April - 2 May, 2014, Vienna,  
2 Austria, Geophysical Research Abstracts, 16, EGU2014-2386, 2014a.

3 Cerdà, A., Jordán, A., Zavala, L., Marqués, M. J., and Novara, A.: The contribution of  
4 mulches to control high soil erosion rates in vineyards in Eastern Spain, EGU General  
5 Assembly 2014, 27 April - 2 May, 2014, Vienna, Austria, Geophysical Research Abstracts,  
6 16, EGU2014-2386, 2014b.

7 Ebisemiju, F. S.: Sediment delivery ratio prediction equations for short catchment slopes in a  
8 humid tropical environment, *J. Hydrol.* 114, 191-208, 1990.

9 Eykelbosh, A. J., Johnson, M. S., and Couto, E. G.: Biochar decreases dissolved organic  
10 carbon but not nitrate leaching in relation to vinasse application in a Brazilian sugarcane soil,  
11 *J. Environ. Manage.*, 149, 9-16, 2015.

12 Españ-Gamboa, E., Mijangos-Cortes, J., Barahona-Perez, L., Dominguez-Maldonado, J.,  
13 Hernández-Zarate, G., and Alzate-Gaviria, L.: Vinasses: characterization and treatments,  
14 *Waste Manage. Res.*, 1-16, 2011.

15 Haghighi, M., Hayati, B., and Momeni Choleki, D.: Identification of factors affecting adoption  
16 of soil conservation practices by some rainfed farmers in Iran. *J. Agr. Sci. Tech.*, 16: 957-967,  
17 2014.

18 Hazbavi, Z. 2013. Soil erosion control by application of polyacrylamide to minimize its  
19 residues in runoff and sediment. M.Sc Thesis, Iran, Tarbiat Modares University. 98 p.

20 Hazbavi, Z., Sadeghi, S. H. R., and Younesi, H.: Analysis and assessing effectability of runoff  
21 components from different levels of polyacrylamide, *Water Soil Resour. Conserv. J.*, 2(2), 1-  
22 13, 2013.

23 Gholami, L., Sadeghi, S. H. R., and Homaei, M.: Straw mulching effect on splash erosion,  
24 runoff and sediment yield from eroded plots, *Soil Sci. Soc. Am. J.*, 77, 268-278, 2013.

25 Girmay, G., Singh, B. R., Nyssen, J., and Borrosen, T.: Runoff and sediment associated  
26 nutrient losses under different land uses in Tigray, Northern Ethiopia, *J. Hydrol.* 376, 70-80,  
27 2009.

28 Jiang, Z. P., Wei, G. P., Liao, Q., Su, T.M., Meng, Y. C., Zhang, H. Y., Lu, C. Y., and Li, Y.  
29 R.: Effect of long-term vinasse application on physical properties of soil in sugarcane fields.  
30 *J. Guangxi Agr. Sci.*, 41(8), 795-799, 2010.

31 Karami, A., Homaei, M., Afzaliniab, S., Ruhipour, H., Basirat, S.: Organic resource  
32 management: impacts on soil aggregate stability and other soil physico-chemical properties.  
33 *Agr. Ecosyst Environ.*, 148, 2-28, 2012.

1 Kukal, S. S., and Srakar, M.: Laboratory simulation studies on splash erosion and crusting in  
2 relation to surface roughness and raindrop size, *J. Indian Soc. Soil Sci.* 59 (1), 87-93, 2011.

3 Loch, R. J., and Donnollan, T. E.: Effects of the amount of stubble mulch and overland flow  
4 on erosion of a cracking clay soil under simulated rain, *Aust. J. Soil. Res.*, 26(4), 661-672,  
5 1988.

6 Madejón, L., López, R., Murillo, J. M., and Cabrera, F.: Agricultural use of three (sugar-beet)  
7 vinasse composts: effect on crops and chemical properties of a cambisol soil in the  
8 Guadalquivir river valley (SW Spain), *Agr. Ecosyst Environ.*, 84, 55-65, 2001.

9 Margesin, R., Cimadom, J., and Schinner, F.: Biological activity during composting of  
10 sewage sludge at low temperature, *Int., Biodeter., Biodegr.*, 57, 88-92, 2006.

11 Newson, M.: *Land, water, and development: sustainable management of river basin systems*,  
12 *Taylor & Francis e-Library*, 460 p, 2002.

13 Nicolás, C., Masciandaro, G., Hernández, T., Garcia, C.: Chemical-structural changes of  
14 organic matter in a semi-arid soil after organic amendment, *Pedosphere*, 22(3), 283-293,  
15 2012.

16 Ojeda, G., Alcaniz, J. M., and Ortiz, O. Runoff and losses by erosion in soils amended with  
17 sewage sludge, *Land Degrad. Dev.*, 14, 563-573, 2003.

18 Pieri, L., Bittelli, M., Wu, J. Q., Dun, Sh., Flanagan, D. C., Pisa, P. R., Ventura, F., and  
19 Salvatorelli, F.: Using the water erosion prediction project (WEPP) model to simulate field-  
20 observed runoff and erosion in the Apennines Mountain Range, Italy, *J. Hydrol.*, 336, 84-97,  
21 2007.

22 Prado, R. de M., Caione, G., Campos, C. N. S.: Filter cake and vinasse as fertilizers contributing to  
23 conservation agriculture. *Appl. Environ. Soil Sci.*, <http://dx.doi.org/10.1155/2013/581984>, 1-8,  
24 2013.

25 Ribeiro, B. T., Lima, J. M. D., Curi, N., and Oliveira, G. C. D.: Aggregate breakdown and  
26 dispersion of soil samples amended with sugarcane vinasse, *Scientia Agricola* 70(6), 435-441,  
27 2013.

28 Rigane, M. K., and Medhioub, K.: Assessment of properties of Tunisian agricultural waste  
29 composts: application as components in reconstituted anthropic soils and their effects on  
30 tomato yield and quality, *Resour. Conserv. Recy.*, 55, 785-792, 2011.

31 Sadeghi, S. H. R., Moatamednia, M., and Behzadfar, M.: Spatial and Temporal Variations in  
32 the Rainfall Erosivity Factor in Iran, *J. Agric. Sci. Technol.*, 13, 451-464, 2011.

1 Sadeghi, S. H. R., Moosavi, V., Karami, A., and Behnia, N.: Soil erosion assessment and  
2 prioritization of affecting factors at plot scale using the Taguchi method, *J. Hydrol.*, 448-449,  
3 174-180, 2012.

4 Sadeghi, S. H. R., Gholami, L., Sharifi, E., Khaledi Darvishan, A., and Homaei, M.: Scale  
5 effect on runoff and soil loss control using rice straw mulch under laboratory conditions,  
6 *Solid Earth*, 6, 1–8, 2015a.

7 Sadeghi, S. H. R., Gholami, L., Homaei, M., and Khaledi Darvishan, A.: Reducing sediment  
8 concentration and soil loss using organic and inorganic amendments at plot scale, *Solid Earth*,  
9 6, 445–455, 2015b.

10 Sadeghi, S.H.R., Hazbavi, Z., and Kiani Harchegani, M.: Controllability of runoff and soil  
11 loss from small plots treated by vinasse-produced biochar. *Sci. Total Environ.* 541 (2016),  
12 2016 483–490.

13 Sadeghi, S. H. R., Hazbavi, Z., and Younesi, H.: Sustainable watershed management through  
14 applying appropriate level of soil amendments, *Sustainable Watershed Management-  
15 Proceedings of the 2nd International Conference on Sustainable Watershed Management,  
16 SUWAMA 2014*, 183-185, 2014.

17 Sheoran, V., Sheoran, A. S., and Poonia, P.: Soil reclamation of abandoned mine land by  
18 revegetation: A Review, *Int. J. Soil Sediment Water*, 3(2), 2010. Available at:  
19 <http://scholarworks.umass.edu/intljssw/vol3/iss2/13>.

20 Tejada, M., and Gonzalez, J. L.: Beet vinasse applied to wheat under dryland conditions  
21 affects soil properties and yield, *Eur. J. Agron.*, 23, 336-347, 2005.

22 Tejada, M., and Gonzalez J. L.: Effects of two beet vinasse forms on soil physical properties  
23 and soil loss, *Catena*, 68: 41-50, 2006a.

24 Tejada, M., Gonzalez, J. L.: The relationships between erodibility and erosion in a soil treated  
25 with two organic amendments, *Soil Till. Res.*, 91, 186-198, 2006b.

26 Tejada, M., and Gonzalez, J. L.: Influence of organic amendments on soil structure and soil  
27 loss under simulated rain, *Soil Till. Res.*, 93, 197-205, 2007.

28 Tejada, M., and Gonzalez, J. L.: Influence of two organic amendments on the soil physical  
29 properties, soil losses, sediments and runoff water quality, *Geoderma*, 145, 325-334, 2008.

30 Tejada, M., Garcia, C., Gonzalez, J. L., and Hernandez, M. T.: Organic amendment based on  
31 fresh and composted beet vinasse: influence on physical, chemical and biological properties  
32 and wheat yield, *Soil Sci Soc Am. J.*, 70, 900-908, 2006a.

- 1 Tejada, M., Hernandez, M. T., and Garcia, C.: Application of two organic amendments on  
2 soil restoration: effects on the soil biological properties, *J. Environ. Qual.*, 35, 1010-1017,  
3 2006b.
- 4 Tejada, M., Moreno, J. L., Hernandez, M. T., and Garcia, C.: Application of two beet vinasse  
5 forms in soil restoration: effects on soil properties in an arid environment in southern Spain,  
6 *Agr. Ecosyst. Environ.*, 119, 289-298, 2007.
- 7 Tejada, M., Garcia-Martinez, A. M., and Parrado, J.: Effects of a vermicompost composted  
8 with beet vinasse on soil properties, soil losses and soil restoration, *Catena*, 77(1), 238-247,  
9 2009.
- 10 Thompson, C. H., and Beckmann, G. G.: Soils and land use in the Toowoomba area, darling  
11 downs, Queensland. CSIRO Australia, Soil land use series, 28, 78 p, 1959
- 12 Zornoza, R., Faz, A., Martínez-Martínez, S., Acosta, J. A., Gómez-López, M. D., and Avilés-  
13 Marín, S. M.: Marble waste and pig slurry increment soil quality and reduce metal availability  
14 in a tailing pond, *Publicado en Terra Latinoamericana*, 31, 105-114, 2013.

Table 1. Runoff rate (ml m<sup>-2</sup>) under different vinasse treatments in each study 0.25 m<sup>2</sup>-plot

Vinasse rate (l m <sup>-2</sup> )		0 (Control)	0.5	1.0	1.5
Sample No.	1	17769.532	12699.720	11884.040	17679.116
	2	15354.972	16970.640	20086.312	20518.280
	3	21627.164	18646.160	15849.736	17445.804
Average		18250.556	16105.508	15940.028	18547.732

Table 2. Results of ANOVA on effect of vinasse on runoff volume, runoff commencement and cessation times

Variable	Comparison	Sum of Squares	df	Mean Square	F-value	Significance level
<b>Total Runoff Volume (ml)</b>	Between Groups	1069690.241	3	356563.414	0.583	0.643
	Within Groups	4895168.190	8	611896.024		
	Total	5964858.431	11			
<b>Commencement time (min)</b>	Between Groups	5.751	3	1.917	9.103	0.006
	Within Groups	1.685	8	0.211		
	Total	7.436	11			
<b>Cessation time (min)</b>	Between Groups	2.154	3	0.718	57.560	0.000
	Within Groups	0.100	8	0.012		
	Total	2.254	11			

Table 3. The soil loss amount under different vinasse treatments in each plot (g m<sup>-2</sup>)

Vinasse rate (l m <sup>-2</sup> )		0 (Control)	0.5	1.0	1.5
Sample No.	1	230.468	100.280	155.960	240.884
	2	325.028	269.360	241.688	241.720
	3	272.836	333.840	150.264	154.196
Average		276.112	234.492	182.636	212.268

Table 4. Results of analysis of variance of effect of vinasse on total soil loss

Variable	Comparison	Sum of Squares	df	Mean Square	F-value	Significance level
<b>Total Soil Loss</b>	Between Groups	872.170	3	290.723	0.848	0.506
	Within Groups	2743.181	8	342.898		
	Total	3615.351	11			



Figure 1. A general view of experimental setup at Rainfall and Soil erosion Simulation  
Laboratory of Tarbiat Modares University, Iran

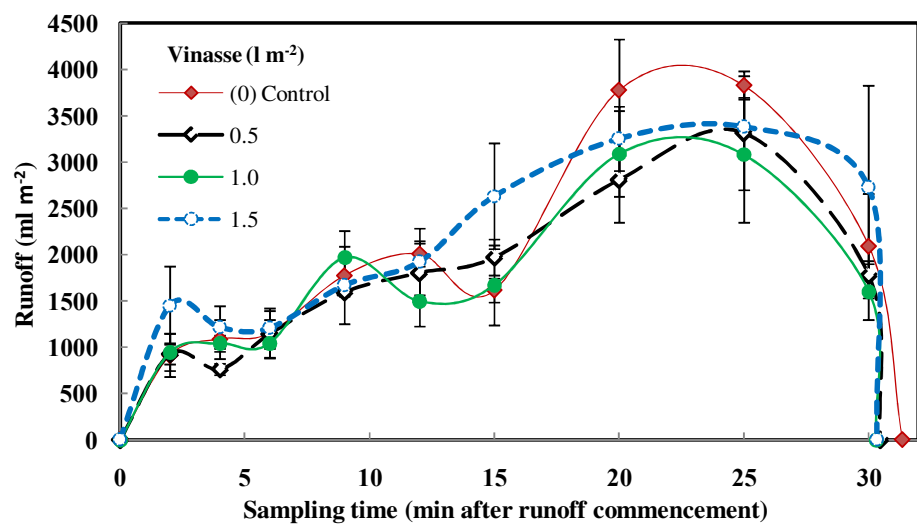


Figure 2. Variations of runoff volume under different vinasse treatments and under study conditions ( $0.25 \text{ m}^2$ -small plot, rainfall intensity of  $72 \text{ mm h}^{-1}$  and experiment duration of 30 min)

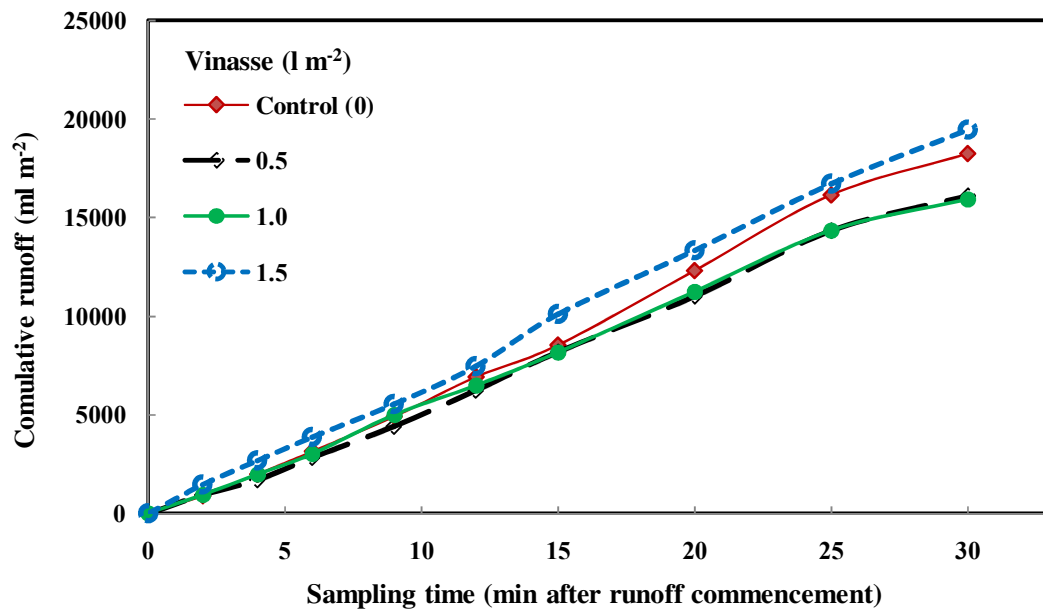


Figure 3. Variations of cumulative runoff under different vinasse treatments and under study conditions (0.25 m<sup>2</sup>-small plot, rainfall intensity of 72 mm h<sup>-1</sup> and experiment duration of 30 min)

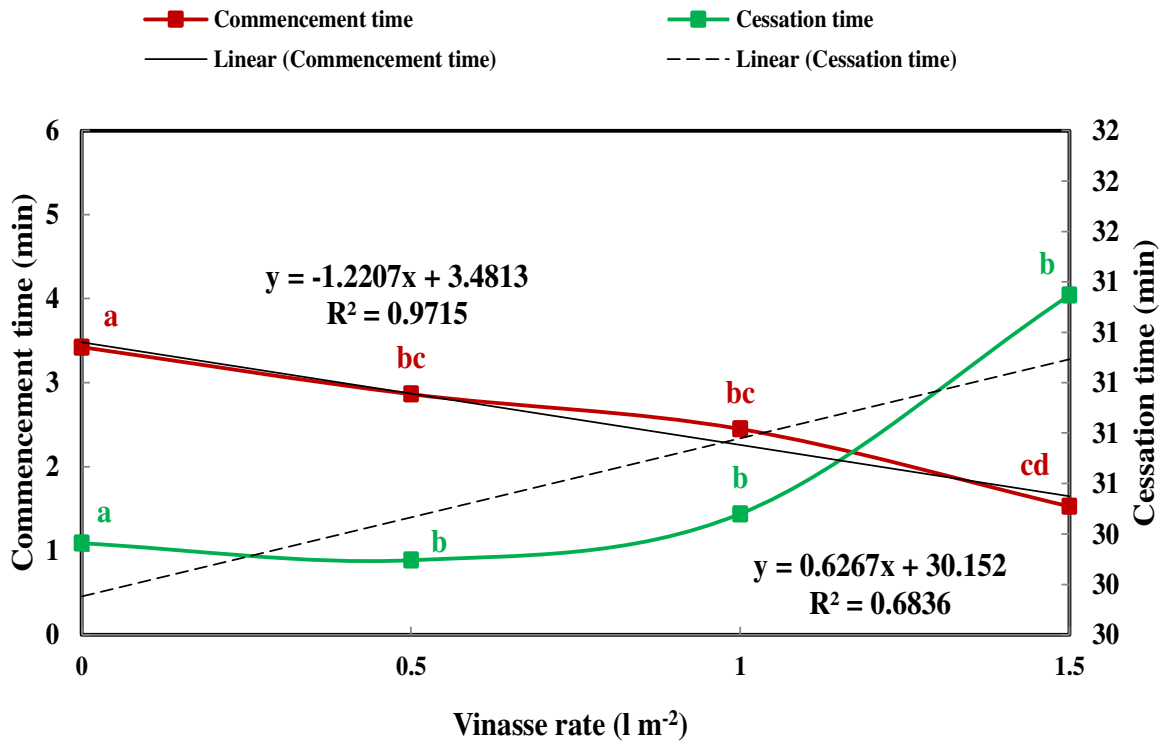


Figure 4. Runoff commencement and cessation times variation under different vinasse treatments and under study condition (0.25 m<sup>-2</sup>-small plot, rainfall intensity of 72 mm h<sup>-1</sup> and experiment duration of 30 min)

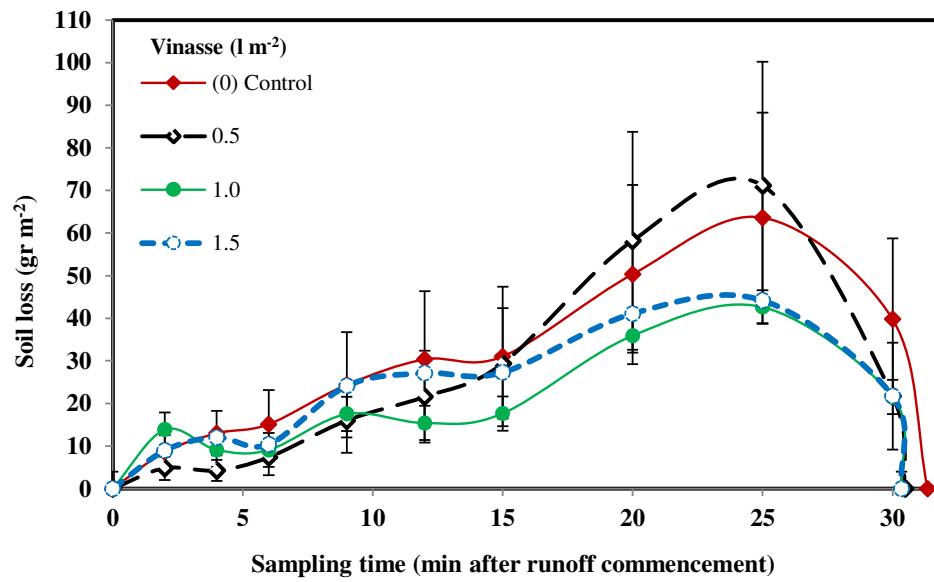


Figure 5. Variations of soil loss under different vinasse treatments and under study conditions (0.25 m<sup>2</sup>-small plot, rainfall intensity of 72 mm h<sup>-1</sup> and experiment duration of 30 min)

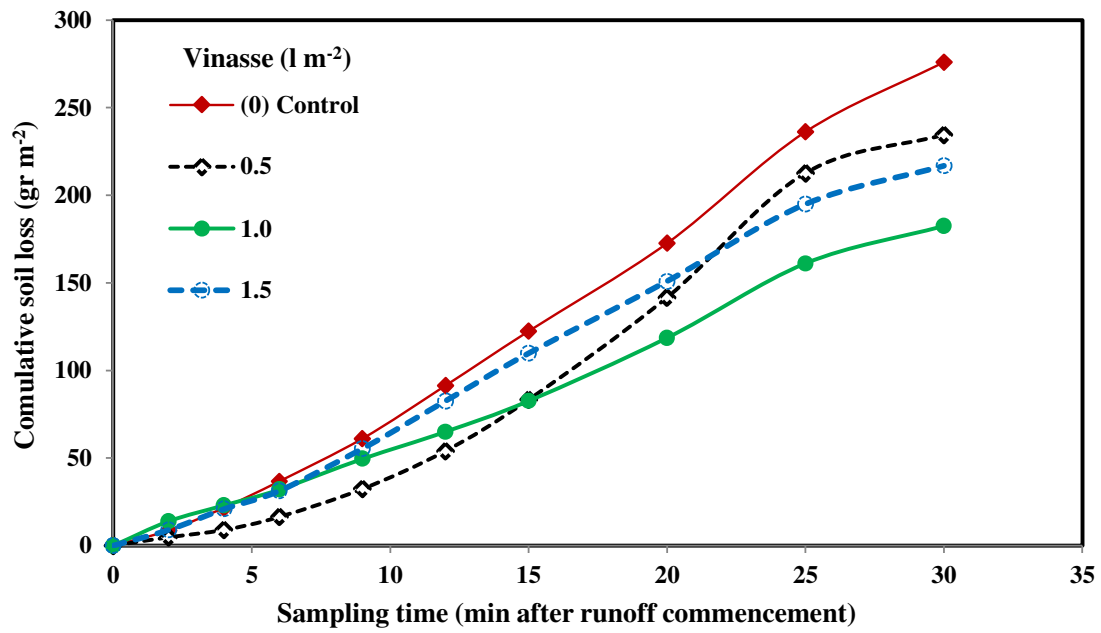


Figure 6. Variations of cumulative soil loss under different vinasse treatments and under study conditions (0.25 m<sup>2</sup>-small plot, rainfall intensity of 72 mm h<sup>-1</sup> and experiment duration of 30 min)