Effects of converting forest to the rainfed lands on soil characteristics in a part of Zagros forests

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Abstract

The forest soils are the key parts of the Earth system that are globally degraded through anthrop induced deforestation, mainly converting to other landuses. The present study was conducted in Gazafolya village located in Merek watershed, Kermanshah, Iran, in which the soil quality of the forest and converted forest (rainfed lands) with the same topographic and geologic conditions were compared. To achieve the study purposes, soil sampling was carried out from the surface soil layers (0-20 cm) at the forest and its adjacent rainfed lands and analyzed in the lab. The data were described and geo-statistically analyzed using the SAS and GS$^+$ softwares. The findings showed that there is no significant difference between soil fractions (sand, silt and clay) in two studied land uses. Bulk density (BD) in the forest and rainfed lands were 1.26and 1.32 gr^{-1}cm^{-3} respectively, indicating significant (p<0.5%) higher level in the rainfed lands. Soil aggregate stability (SA) in the forest and rainfed lands were 63.62 and 52.65 %, respectively showing significant (p<0.5%) lower value in the rainfed lands mainly due to tillage practice. The results also showed that there were no significant differences between soil pH in forest and rainfed lands. It turns out that AS and BD were more imposed by converting forest to rainfed lands compared to the other soil characteristics.

Keywords: Aggregate Stability; Gazafolya; Improper Tillage; Rainfed Lands; Zagros Forest

1. Introduction

Soil provides some services, materials, and sources for human beings which make it necessary dedicate some studies to it. At the global scale, the forest soils are the key parts of the Earth system that are globally degraded through anthrop induced deforestation activities, mainly converting to other landuses. However, the dynamic interaction between vegetation, particularly forest, and soil can help renew both of them. The global forests are estimated to be about four billion hectares (FAO, 2012), although they are shifting to arable lands suffering from deforestation factors. Converting forest is defined as the replacement of natural forests with other forms of land use imposing

serious problems, especially loss of plant and soil diversities associated with land use and cover change, climate change and contamination (Berendse, *et al*., 2015; Brevik, 2015).

The forest conversion to rainfed lands has been the concern of relevant experts and even decision makers in Iran due to its severe negative impacts. This management failure has shared to deforestation and consequently accelerating negative environmental impacts during recent decades. This has estimated about 1.45 Pg of carbon to the total carbon released from 1990 to 2010 in China (Lai *et al*., 2016).

Zagros forests (*Quercuse persica*) are located in the Zagros Mountains, along the west of Iran with an area of 5 million ha, although it used to be approximately 10 million ha before 1970s (Saeed, 2006). Unfortunately, Zagros forests are suffering from severe deforestation phenomenon due to anthropogenic factors such

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as understory cropping, charcoal, grazing, arson fire, and converting to rainfed lands, the most important one, during recent years. Subsequently, improper tillage in the rainfed (converted forest) is the main deforestation challenge in this region leading to huge forest losses. Recent study showed that most of the soil characteristics are affected by improper land utility, particularly heavy grazing (Hossein Jafari *et al.*, 2015),

During 1972-2009, more and more demands for agricultural products and crops price, which provided an incentive for further conversion, led to converting approximately 353000 ha (69%) of these forests mainly to agricultural lands (Henareh Khalyani *et al.*, 2012). Moreover, improper plowing in the Zagros Forest is the other terrible agricultural activity causing problems (Fallahzade, *et al.*, 2011). In fact, tillage is practiced parallel to the slope direction using moldboard plow causing drastic soil disturbance which obviously affects soil properties mainly extrinsic characteristics such as organic carbon, aggregate stability and bulk density as well as erosion hazard in the Zagros areas (Mohammad and Adam, 2010). The soil of this region is geologically inherited from marl deposits dominated by expanded minerals such as smectite (Karimi *et al.*, 2008; Heshmati *et al.*, 2011). This induces a kind of soil with high degradation potential sharing off-site impacts such as global warming, siltation and eutrophication phenomena.

From all off-site impacts, due to negative change in AS and BD is the most considerable one in the hilly regions of Zagros forest. The study by Quinton *et al.* (2006), explored that soil erosion and SOC flux by improper tillage practice is four time more than perpendicular to the slope. In addition, a vast part of disturbed SOC is removed from hill-top displacing in the drainage system due to tillage practice (Karlen *et al.*, 2008). However, it is considered as one of the most important soil degradation processes on sloping agricultural soil whose greatest risk is under moldboard plowing (Blanco and Lal, 2008).

The fine grained soils of Zagros region mainly comprise clay which is susceptible to piping, gully and landslide incidence, especially in the place where plant biomass has been curtailed by improper agricultural activities. Piping phenomenon occurs due to runoff concentrating in the macro pores such as cracks and small fractures. Dispersion on the hillside accelerates piping process due to weakening of the vegetation resulting in undermining and collapse of top-layer and finally gully formation (Morgan, 2005).

By and large, land use change is more frequent in the highlands due to population pressure, government policy, market demand, climate change and urbanization (Valentin *et al.*, 2008). These processes occur in most parts of Zagros Mountains in Iran. Field observation in several parts indicates that recent rainfed farms in the neighbor of forests faced piping, gully development and rill erosion which are mainly due to tillage practice and poor vegetation cover during rainfall season. The present study aimed at evaluating the soil aggregate stability and bulk density of Zagros forests affected by conversion of forest to rainfed lands in the Gazafolya village located in the upper Merek watershed, Kermanshah (Central Zagros), Iran.

2. Materials and Methods

2.1. The study area

The present study was carried out during September and October 2013, in Gazafolya, Merek catchment, Zagros forest, located 35 km south of Kermanshah, Iran (UTM WGS 84 N38; X= 693749-700368, Y= 3767614 – 3771684) (Figure 1). The site includes the plain and hilly lands with forest and agricultural areas. The mean annual precipitation and temperature of the region are 450 mm and 17 °C, respectively representing the semiarid region.

This catchment is geologically made of a series of anticline and syncline with local fold and fault dips that are dominated by limestone, sandstone, shale and marls deposits of Cretaceous, Pleistocene and Holocene ages. The soil is mostly clayey and silty in nature with high amount of calcite. The CEC and pH of the soil is high. Land degradation in this catchment is mainly caused by soil erosion (particularly inter-rill, rill, gully and landslide), which is promoted by deforestation, overgrazing and improper tillage activities.

The sedimentary rocks geologically are made of limestone, sandstone, shale and marls deposits handed down from Pleistocene and Holocene ages. The soil is mostly clayey and silty in nature with high amount of smectite and calcite. The forest is predominated by local oak (*Quercus percia*). A majority of studies have classified these forests into the Irano-Anatolian phytogeography sub-region (Zohary, 1973; Sabeti, 1993). However, Zagros Forests are suffering from deforestation phenomenon due to anthropogenic land degradation factors,

especially forest clearance nearby agricultural lands. Furthermore, land degradation is defined as soil erosion (particularly inter-rill, rill, gully

and landslide), improper tillage practice, overgrazing and over application of chemical inputs mainly fertilizers.
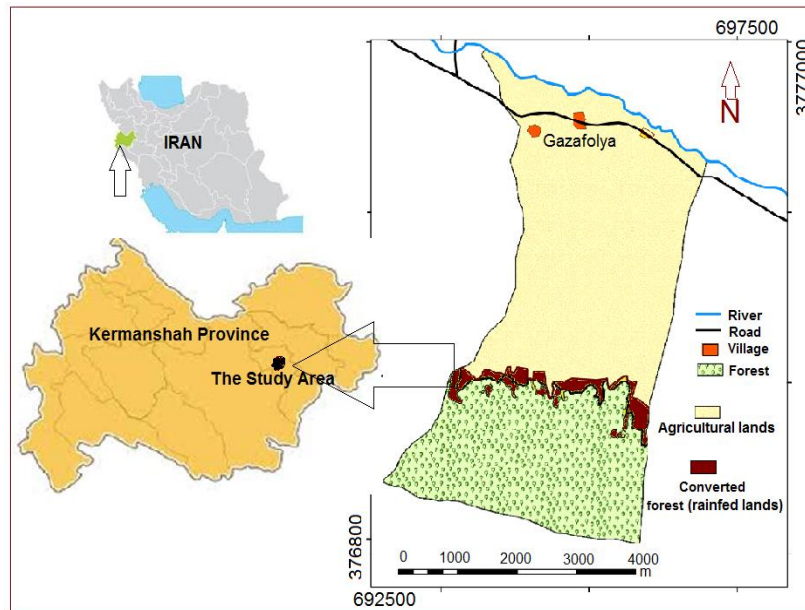

Fig. 1. A map showing the location of the study area (Gazafolya) in Kermanshah and Iran

2.2. Geomorphological characteristics of the selected sites

The selected rainfed and its upward forest share the same geological, topographical (slope gradient, sloe aspect and elevation), soil order and erosion features. Each homogenous site is called a geomorphological facies with specific geological, topography, land use and erosion within a catchment (Ahmadi, 2003). Kashkan formation (given local name by geological survey of Iran) is the dominant geological formation of the region comprising of clay stone, siltstone and sandstone, inter-layered with marl deposits (Karimi-Bavandpoor *et al.*, 1999). Field observations also indicate a thin limestone layer sandwiched among fine grained marl layers. Moreover, landslide is considered as the main degradation feature initiated by piping and cracking processes. The slope steepness and altitude ranged from 15 to 20 percent with northern direction and 1500 to 1600 meter respectively. Soil is Entisols with A and C horizons (Soil Survey Staff, 2003). As a matter of fact, forest converting has been increased during recent decade by local inhabitants either gradually via plowing or direct clearance, arson fire and logging activities inducing a new land use known as rainfed lands.

2.3. Soil sampling and analysis

Thirty-five soil samples were collected from depth of 0-20 cm followed by stratified random soil sampling whose coordinates were recorded by global positioning system (GPS). The dried soil samples were sieved through 2 mm mesh sieve analyzed in the local soil laboratory. The particle size distribution and soil texture were determined by hydrometric method (Soil Survey Laboratory Staff, 1991). Natural core of the soils was taken from the surface soil to measure the bulk density using core bulk apparatus (Eijikelkamp apparatus with 100 cm^3 cylinder; The Netherlands) and its value was calculated by weighting before and after drying in an oven at 105 °C for 24 hours.

The aggregate stability (AS) of the soils was measured by a method using wet-sieving procedure of Teh and Talib (2006). The pH of the saturated soil paste was measured by a pH meter as outlined by Ryan *et al*, (2001).

2.4. Statistical and geostatistical analysis

Descriptive statistical analyses including mean, maximum, minimum, standard deviation (SD), coefficient of variation (CV) and t-test were carried out using SAS software (version 6.12). The geo-statistical analysis, including semi-variogram model (autocorrelation and interpolation) and kriging procedure, was

performed to evaluate the degree of spatial variability of each soil feature using the GS+ software (version 9). The normality of the data was also checked through this software based on skewness coefficient. The skewness was from -1 to +1 indicating the normality of the data (Virgilio *et al.*, 2007).

3. Results and Discussion

3.1. The effects of converting forest on particle sizes distribution

The findings of descriptive statistical and geo-statistical analysis of soil particle sizes distribution (sand, silt and clay) are presented in Tables 1 and 2. The average sand particle of both sites is about 26% indicating no significant difference between them. The values of silt in

the forest and rainfed were 41.2 and 38.4% respectively. Moreover, their clay contents were about 33 and 35 percent respectively. The t-test analysis also indicated that there is no significant difference between two land uses for silt and clay contents (Table 1). The nugget ratio of geo-variance analysis revealed an almost moderate to high spatial variation for soil particle size distribution (Table 2). Strong spatial dependency properties could be controlled by intrinsic factors (Cambardella *et al*, 1994; Ayoubi *et al.*, 2007). Besides, high levels of clay and silt in both sites are related to high content of fine grained parent material. It is confirmed through regression coefficient of kriging model (Jafarian *et al.*, 2011) that was more reliable for soil particles in the rainfed site (Table 3).

Table 1. Descriptive statistics for soil physical variables in the forest and rain-fed in the Gazafolya, Merek, Iran

Variable	Land-use	Mean	SD	S. Var	Min	Max	N	Ske.	T-test(Pr> F)
Sand%	Forest	26.00	10.61	112.60	11.00	54.00	19	0.94	0.93NS
	Rainfed	26.30	7.12	50.70	18.00	42.00	16	0.74	
Silt%	Forest	41.20	8.65	74.80	32.00	60.00	19	1.06	0.24NS
	Rainfed	38.40	4.92	24.30	30.00	48.00	16	0.42	
Clay%	Forest	32.70	9.90	99.60	12.00	52.00	19	-0.36	0.41NS
	Rainfed	35.30	7.90	62.50	21.00	47.20	16	-0.56	
AS%	Forest	63.62	4.23	17.90	57.50	70.75	11	0.29	0.003*
	Rainfed	52.65	9.98	99.65	40.04	68.25	12	0.25	
BD (g/cm³)	Forest	1.26	0.047	0.0035	1.20	1.370	11	1.13	0.034*
	Rainfed	1.32	0.095	0.008	1.17	1.42	12	-0.73	
pH	Forest	7.70	0.236	0.05	7.20	8.32	19	0.44	0.051NS
	Rainfed	7.56	0.124	0.015	7.30	7.80	16	-0.80	

AS= Aggregate Stability, BD= Bulk Density, S. Var = Sample Variance, Ske.= Ske.wness,
* = significant difference at 0.05% level and NS = no significant difference

Table 2. Coefficients of the semivariogram models of soil variables in the forest and rain-fed in the Gazafolya, Merek, Iran

Variable	Land-use	Model	Nugget (Co)	Sill (Co + C)	Co/ (Co+C)	Range A (m)	R²	RSS	Spatial variation class*
Sand	Forest	spherical	86.90	235.50	0.37	19410	0.25	7214	S
	Rainfed	linear	41.40	46.61	0.89	4865	0.56	3597	W
Silt	Forest	exponential	71.10	142.10	0.50	21100	0.02	3122	M
	Rainfed	spherical	12.35	38.40	0.32	3520	0.23	2048	M
Clay	Forest	exponential	92.90	185.60	0.50	21100	0.05	12507	M
	Rainfed	exponential	59.40	119.50	0.50	21100	0.089	3012	M
AS	Forest	linear	15.01	15.01	1.00	4946	0.005	4152	M
	Rainfed	exponential	88.60	215.50	0.41	10610	0.24	5152	M
BD	Forest	spherical	0.0003	0.0085	0.35	11700	0.499	1.85E-05	M
	Rainfed	spherical	0.0006	0.0091	0.65	1620	0.193	2.6E-04	M
pH	Forest	exponential	0.051	0.1026	0.49	14040	0.080	1.48E-03	M
	Rainfed	spherical	0.0048	0.0200	0.24	1580	0.204	4.79E-04	M

AS= Aggregate Stability, BD= Bulk Density, * Nugget ratio [Co/(Co+C)] <0.25= S (Strong spatial dependence),
0.25<Co/(Co+C) <0.75 = M (moderate spatial dependence), Co/(Co+C) >0.75= W (Weak spatial dependence),
R= Random [Co=(Co+C), variable is described as spatially independent and completely random] (Cambardella, *et al*, 1994)

3.2. Converting forest affecting BD and AS

The soil bulk density (BD) in the forest and rainfed was found as 1.26gr⁻¹ cm⁻³ and 1.32 gr⁻¹cm⁻³ respectively which was significantly (p<0.05%) increased in the rainfed site (Table 1). A spherical semi-variogram models proved that there was a moderate spatial dependency

for BD in the sites, although spatial dependency of the forest was a bit more (0.35 nugget ratio in the forest compared to 0.65 in the rainfed affecting more variation within rainfed by extrinsic factors such as agricultural activities.
The field verification also showed that heavy agricultural machinery traffic and improper tillage practice during April and May (when soil

is moist) as well as crop residue burning lead to soil compaction and erosion which makes BD level to be increased. Furthermore, it turned out that there are organic and green potential manures which have been ignored by local farmers. The study by Hemmat *et al.* (2010) in the semiarid agricultural area of Iran revealed that BD is significantly improved by organic manures leading to soil sustainable index and moisture content followed by over 7 years manure application. Besides, from all soil physicochemical properties in the Zagros Forest, SOC and BD are more vulnerable to deforestation phenomenon (Nael *et al.,* 2004), while reduced tillage and crop residue turnover decreased at least 10% of bulk density (Dam *et al.*, 2005).

The levels of aggregate stability (AS) were 63.62 and 52.65 % in the forest and rainfed sites respectively indicating a significant reduction in the rainfed followed by spatial variation the same as bulk density (Table 1). This adverse change in AS is imposed by land use management. Significant changes in BD and AS could be associated with tillage practice which is practiced parallel to the slope gradient using moldboard plow which causes severe rill erosion. This way of plowing can displace soil three times more than chisel tillage (Morgan, 2005). In contrast, sequestered SOC through shifting of rainfed to forest and grassland could increase the coarser aggregate. A study by Liu *et al.* (2014), revealed that aggregate formation and its size are associated closely with SOC in the farmlands which tended to be smaller-sized one, whereas under forest and grassland resulted in macro soil aggregation. Although, high soil carbonate and low sodium contents have positive effect on aggregate stability in the Mediterranean regions (Farid Giglo *et al*, 2014). Moreover, soil aggregation is triggered by accumulation of SOC (Moreno-delas Heras, 2009). Besides, soil erosion makes an exponential reduction in aggregate stability. Yan *et al.* (2008) reported that most of the soil aggregates are broken through inter-rill erosion. The coarse soil aggregate is reduced mainly by long-term conventional tillage practices. The study of Li and Pang (2010) on a silty clay loam soil in China revealed that long-term practices of this tillage reduced 22% of coarse aggregates while increased 34% of fine soil aggregates.

3.3. Converting forest affecting soil pH

The soil pH of the forest and rainfed was 7.70 and 7.56, respectively with moderate spatial dependency. In addition, t-test analysis did not show any significant differences for pH in the sites (Tables 1 and 2). Soil pH had the minimum spatial variability compared to other soil properties. In fact, land use practices contribute to less spatial variation for pH (Kilic *et al*., 2012).

Average soil carbonate content in the forest (32.7 %) was a bit higher than the rainfed sites (30.02%) with no significant difference between them (Table 1). The geo-statistic parameters show a weak and random spatial dependency for carbonate (Table 2). However, randomized distinct classes of spatial dependency show the severe effects of both rill erosion and tillage practices on surface soil leading to the disturbance of carbonates with high sample variance in the rainfed site (Table 1). If the nugget value equals sill, soil variable is described as spatial independence and completely random (Cambardella *et al*., 1994) influencing by soil erosion (Jabro *et al*., 2010). It is proved by the other similar study (cambardella *et al*., 1994; Jafarian *et al*., 2011). Having lower density than mineral particles, depletion of SOC through soil erosion and sedimentation is more severe because it is mainly stored in the soil surface which can be detached and transported by rainfall (Lal, 2005). Tillage practice contributes to SOC loss in the agricultural areas, especially in the top-soils. Therefore, SOC and AS in tilth lands are apparently more sensitive to short-term tillage practices in the semiarid calcareous soil of Iran (Kabiri *et al*., 2015). Spatial variability of organic carbon is controlled by plough system, soil texture, soil disturbance, climatic and topographic factors (Karlen *et al*., 2008). Soil disturbance cause soil nutrients depletion and moisture loss subsequently crops yield (Miralles *et al*., 2009). It is known as the tillage erosion affecting SOC, AS and gully development (Blanco and Lal, 2008; Bechman *et al*, 2009; Rosa *et al*., 2009; Senthikumar, 2009).

The study of Kilic *et al*. (2012) revealed that soil quality is decreased significantly through tillage practice. Moreover, the variables of cultivated soils had a lower nugget value than the grassland. Finally, the change in soil coarse aggregate stability mainly correlated to tillage system (Kabiri *et al*, 2015). Farm management in terms of minimum machinery traffic, chisel plough, turnover of crops residue and precise application of chemicals inputs are considered as the proper practices in these regions (Hamza and Anderson, 2005). Finally, due to interaction between understory vegetation and soil in the forest, vegetation covers lead to increasing soil

moisture capacity (Safari and Kazemi, 2016), subsequently biodiversity of Zagros forest share in sustaining soil, agriculture and environmental services. Climate change in Zagros region is characterized by deficit annual precipitation and adversely increasing temperature (Babaeian *et al*., 2015), thereby public awareness and short-term measures such as forest protection are urgently needed for curtailing converting forest in Zagros region.

Table 3. Parameters of Kriging model validation for soil variables in the forest and rain-fed in the Gazafolya, Merek, Iran

| Soil variable	Land-use	Regression Coefficient	Standard Error (SE)	R^2	Y intercept	SE prediction
Sand	Forest	-3.32	1.12	0.35	114.35	8.65
	Rainfed	16.00	1.12	1.00	438.00	8.65
Silt	Forest	-0.511	1.62	0.006	60.91	7.90
	Rainfed	16.00	0.00	1.00	672.00	0.00
Clay	Forest	9.27	1.35	0.73	341.80	5.14
	Rainfed	15.00	1.35	1.00	564.80	5.14
AS	Forest	-8.74	2.06	0.66	619.33	2.44
	Rainfed	-1.80	1.27	0.17	148.06	9.11
BD	Forest	0.27	0.44	0.04	0.92	0.06
	Rainfed	-0.03	0.85	0.00	1.37	0.09
pH	Forest	0.69	0.98	0.03	2.35	0.23
	Rainfed	-1.58	0.69	0.27	19.53	0.11

AS= Aggregate Stability, BD= Bulk Density
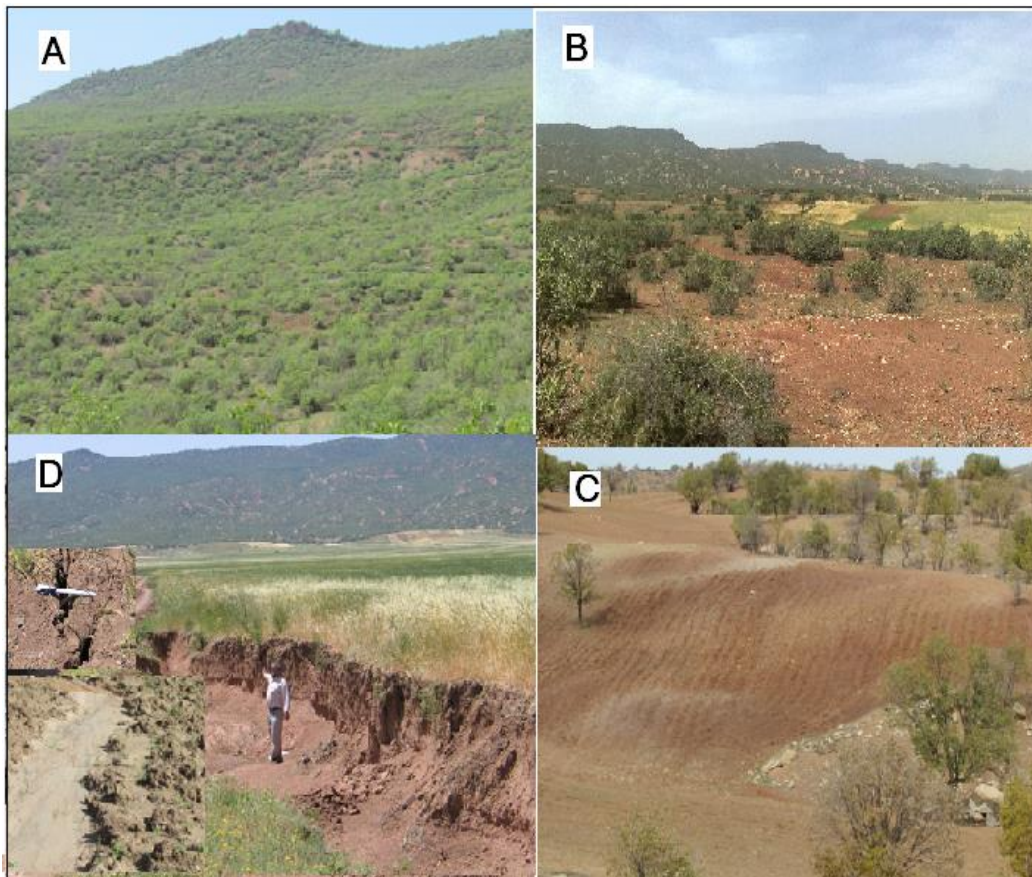
Fig. 2. Virgin Zagros forests (A); Converting Zagros Forests to rain-fed lands (D); up-down the slope tillage practice in the converted forest (rain-fed lands); and major impacts of converting forest including cracking, gulling and siltation (D)

4. Conclusion

The anthropogenic deforestation in the Zagros forest is accelerating seriously over the time. From all deforestation practices, forest conversion to the slope tilth lands is the main challenge that not only affects soil properties but also lead to some environmental impacts. The findings, based on both classical and geo-statistical analysis, revealed that the crucial extrinsic soil features including organic carbon, aggregate stability and bulk density are

significantly affected by the aforesaid land use shifting and high spatial variation in the rainfed site. In contrast, there were no significant difference for soil particle size distribution (sand, silt and clay) and pH in forest site compared with that rain-fed site. Besides, the spatial variation does not meet any significant level. In conclusion, AS and BD are more imposed by deforestation compared to the other soil characteristics. Furthermore, tillage practice which is carried out parallel to the slope gradient should be regarded as a negative factor on soil disturbance in the Zagros forests leading to off-site impacts such as siltation, global warming and eutrophication phenomena. It should be said that the improvement of tillage system is regarded as a necessary program to curtail the current improper activities in this region. Finally, the present study emphasizes on the site-specific management using variography and Kriging model of geo-variance model to precise soil input application and sustainable environment.

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