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Mitigating drought induced-mortality in the semiarid forests through runoff harvesting system; as a short-term adaptation measure

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Abstract

The effects of climate changes are generally expected to reduce the growth and survival of forests, particularly in semiarid regions. This study was conducted to demonstrate the effects of runoff harvesting technique on the reduction in forest tree dieback phenomenon in the Zagros forests, Iran. In order to evaluate this hypothesis, runoff was harvested through the crescent shaped trench (CST) affecting soil moisture storage. The selected forest site is located in Kalehzard, Kermanshah, in Zagros region, western Iran. The experiment was a randomized complete block design with four treatment plots: trench with protection (T+PT), protection treatment (PT), trench without protection (T-PT), and control treatment (CT). Three years of comparative monitoring explored that dieback rate increased followed by the reduction in the average annual precipitation and worsening temperature conditions. Hence, T+PT treatment led into a significant reduction in dieback rate (37.7 tree ha-1) and re-growing of certain stands (including total 18.0 tree ha^{-1}) compared to CT. Furthermore, our results demonstrated that T-PT contributed to lower level on dieback reduction (6 tree ha^{-1}) revealing the importance of protection measure which is so effective for the built trench. As a result, micro-catchment could provide soil moisture for the enhancement of forest in semiarid regions, such as Zagros areas.

Keywords: Crescent shaped trench; Kalehzard site; Forest dieback; Semiarid forests

Highlights

- Our field verification demonstrated that 30% of Zagros forest stands were affected by climate changes
- We evaluated the effects of runoff harvesting on curtailing the forest dieback phenomenon.
- The crescent shaped trench (CST) was constructed for runoff harvesting and soil moisture storage was recorded with Time Domain Reflectometry (TDR).
- Our findings revealed that CST positively combat forest mortality rate and thereby could be considered as a possible adaptation measure to tackle the issues associated with climate changes.

1. Introduction

The effects of climate changes are generally expected to reduce the growth and survival of forests. This reduction not only predisposes them to be disturbed by insects and diseases, but also increases the vulnerable to dieback phenomenon ones to higher tree mortality (Allen *et al.*, 2010; Chmura *et al.*, 2011, Assal *et al.*, 2016). This event, particularly in semiarid areas, could alter the composition, structure, and biogeography of forests. Currently, this phenomenon has spread

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throughout the Zagros oak Forest (west of Iran). Unlike oak species in Europe (*Q. petraea*) (Scharnweber *et al*., 2011), Zagros oaks *(Q. persica)* are more vulnerable to drought-driven mortality due to severe climate changes affecting a considerable part of this unique heritage. It is estimated that one-third of these forests are victims of mortality phenomenon (Hosseini, 2014; Sadeghi *et al*., 2014; Attarod *et al*., 2015).

Zagros forests cover about 5 million ha, 40% of Iran forests (Sagheb-Talebi, Sajedi, and Yazdian 2003). According to some research, several biotic and abiotic factors, such as extreme weather conditions, drought, storms, heat, and insect fluctuations, are considered to be responsible for the oak reduction (Misik *et al.*, 2013). Therefore, the Zagros forests are severely deforested through socioeconomic and climatic changes (Henareh Khalyani *et al*., 2014). Moreover, meteorological parameters dramatically changed during 2000-2010 (air temperature: +0.6 ˚C; precipitation: -60 mm; relative humidity: -3 %, wind speed: +0.4 m s-1, and ET0: +0.25 mm $d^{-1,}$). This shows that Zagros region is getting drier and warmer coinciding with oak decline (Abasi *et al*., 2011; Attarod *et al*., 2015). This severe drought stress, during 2007-2009in particular, has led to the decrease of plant diversity and a lower productivity of the region (Pourbabaei, *et al*., 2014). Consequently, the forests are known to be increasingly at risk of higher background tree mortality due to climate changes because of soil moisture deficit (Allen *et al*., 2010; Tang and Wang, 2017).

Furthermore, Zagros forests are categorized as non-wood forests and thus, should be protected for sustaining environment while they faced deforestation and severe land degradation aggravating as a result of climate changes and forest mortality.

The aforesaid phenomenon is more serious in semiarid forests due to lower precipitation and higher hydrological loss, such as runoff and evaporation (Babaeian *et al.*, 2015). Despite the drastic increase of water demand during drought tension in semiarid regions, vast amount of precipitation in the hill slope is lost through runoff, which is believed to be a result of anthropogenic activities, such as deforestation, and improper agricultural activities like heavy tillage practice. In fact, both runoff losses and deforestation agents or evaporation processes severely accelerate the mortality of forest trees. Accordingly, micro-catchment runoff harvesting (MCRH) technique could not only control this local runoff and reduce the transmission losses, but also could concentrate it on the plant root area (Ali *et al*., 2010).

Most studies have reported an increasing need for rainwater harvesting and a recognition of its potential (Boers and Ben-Asher, 1982). This technique has been applied in the arid and semi-arid regions in order to minimize the risk of droughts (Adham *et al*., 2016) referring to the assemblage of precipitation on earth surface for beneficial uses, for instance crops, rangeland, tree, and livestock before it evaporates. There are several adapted kinds of MCRH techniques used in the Middle East for 3000 years (Bisoyi, 2006; Muriu-Nganga *et al*., 2017).

As a matter of fact, they are regarded as effective approaches to predicting runoff and storing water in the soil profile. There are certain simple and economical ways for adaptation, namely conserving overland flow and applying it in a way that it could meet the ecological needs of forest during dry seasons (Westgate *et al*., 2013).

However, mitigating the forest tree dieback in the Zagros forests is assumed to be connected with runoff harvesting through micro-catchment system. To examine this hypothesis, the present study aimed to demonstrate the effects of crescent shaped trenches (CST) as the possible MCRH technique to mitigate forest tree dieback phenomenon over three regional drought years.

2. Materials and Methods

2.1. The Study Area

This study was conducted in Kalehzard site located in Kermanshah, west of Iran (UTM; 38S682887E, 3748385N). The average annual precipitation and temperature are respectively 440 mm and 15.2 ºC with a 5-month dry season, which proves that the region is a semiarid one. The winter is so cold that the temperature drops below zero for 90 days during December, January and February. Summer therein is rather hot to cool and dry.

Over 65% of this precipitation occurs in winter, the time when it is not appropriate enough for plant growth (Figure 1). The majority of the relevant studies have classified Zagros forests in Irano-Anatolian phytogeographic sub-region, in which the dominant spices is *Quercus persica* (Zohary, 1973). It regenerated mainly in a coppice stand (vegetative regeneration) in Zagros although there are also rare cases of native seedling regeneration.

The soil in this site is *Entisols* with A and C horizons suffering from erosion hazard due to improper agricultural activities, particularly up-down the slope tillage practice, heavy livestock grazing, and illegal deforestation activities in terms of converting the forest to rain-fed lands, charcoal extraction, and arson fire.

The soils are mostly clayey and silty with high calcite, CEC and pH. Moreover, land degradation in this region is mainly caused by human activities promoting heavy soil erosion, such as inter-rill, rill, gully and landslide.

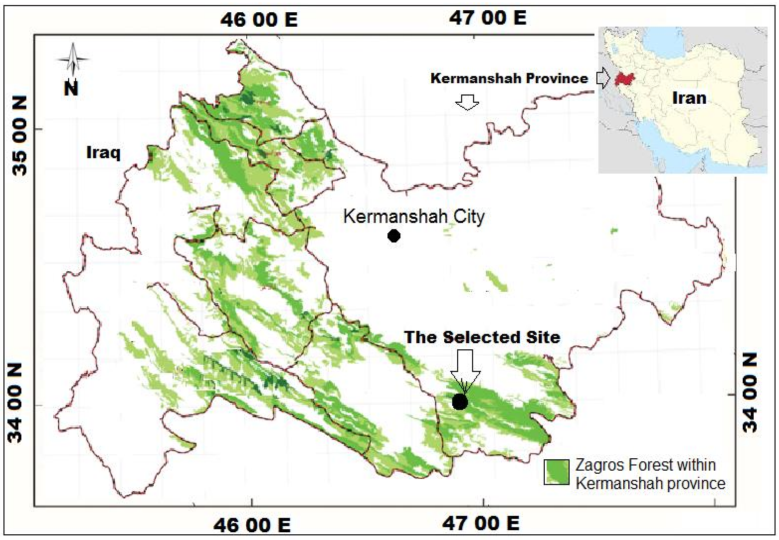

Fig. 1. Location map of the study area (Kalehzard, Kermanshah, Iran)

2.2. Experimental Design

A hill with a 15% slope and south-eastern aspect was chosen as the experimental site to represent the dieback phenomenon in the Zagros forests. The experiment was a randomized complete block design with four treatments and three replications. The following treatments were used: Trench+ Protection Treatment (T+PT), Protection Treatment (PT), Trench without Protection (T-PT), and Control Treatment (CT), resulting in a total of 12 plots (50 × 30 m each) spaced at 10 m intervals. Field survey and data collection were carried out during September 2012–2015. Zagros forests in Iran are nationalized and should be protected as the natural reservoir; hence, these forests are mainly impacted by overgrazing fragmented tillage and cropping as well as illegal logging and charcoal extraction. Thus, protection treatment (T+PT and PT) related to this situation. In contrast, both T-PT and CT are subjected to common deforestation practices known to be mainly overgrazing and branch cutting, which are more frequent in the study area.

2.3. Micro-Catchment Runoff Harvesting

The crescent shaped infiltration trenches were designed is a adaptive micro-catchment runoff harvesting system (MCRHS) and measured within treatments plots. This technique has a lower soil and embankment movement compared to earthy or stones dam which can be built perpendicularly in the flow of runoff. Moreover, it is arranged in staggered rows along the natural contour of the land with the open end facing uphill. Consequently, these trench slow down runoff enabling the harvested water to be used in an effective way. This is particularly advantageous for increasing the soil moisture, especially when the precipitation is scarce (Figure 2).

Responses to climatic stresses at the stand or landscape scale are not well-understood (Chmura *et al*., 2011). To date, there have been no adaptation sign of the trees in the process of climate change, and therefore, runoff utility is more visible in semiarid regions.

Concerning reforestation, these techniques lead to a successful increase of planted trees and their resistance enabling the crops to survive during dry months. This technique is used to rehabilitate degraded, denuded and hardened land for crop growing, grazing or forestry, which can result into a remarkable re-greening of the environment promoting biodiversity (Ackermann *et al*., 2012). Regarding the minimum soil disturbance, the location of each trench was benchmarked and built by local workers following the site selection and plot establishment. The upper levels of the embankments were covered by rocks leading to the dryness of tree branches. Depending on the soil depth and tree density, the trench depth was 40-60 cm along the contour of the land. However, the lower levels of the embankment soil were compacted and covered by local fragmented rocks and dry tree branches. The total number of crescent shaped trench was estimated to be about 183 per hectare.

Soil Moisture Measurement

The volume of soil moisture content within three soil layers (0-15, 20-30 and 30-50 cm) was measured utilizing Time Domain Reflectometry (TDR; model TRIME-FM, MKO equipped with connector waveguide sensor). TDR provides a quick measurement of soil water status on the research station fields (Oweis and Hachum, 2012; Fatas *et al*., 2013). Moreover, the pipe of TDR is performed into undisturbed soil in both basin, downward side of the trenches, and the control site. The percentage of soil moisture content was recorded following each precipitation event. Runoff coefficient was estimated based on landuse, soil texture and slope characteristics as formulated by Hudson (1993) and Mullan (2013).

2.4. Monitoring Tree Dieback within plots

The frequency of both dieback and healthy trees was recorded twice a year and the total number of trees was recorded ahead of the construction of trench within the plots using 100% inventory method. The dried trees within the plots were punctuated and completely rerecorded twice a year during the research period.

2.5. Statistical Analysis

Employing the SAS version $_{6.12,}$ statistical analyses of the experimental data were performed. The statistical processing was mainly ANOVA with a probability of 0.05.

Fig. 2. The constructed crescent shaped infiltration trench in the study area at the first year (a) and using fragmented rock in embankment wall (b)

3. Results

3.1. Dieback Symptoms in the Zagros Forest

On top of abiotic factors, non-anthropogenic agents, diseases and pests, climate change is also considered as an effective factor in the Zagros forest dieback. Therefore, the crown dieback affects the standard stands more than coppice trees. Our findings are in line with those of an investigation by Hosseini (2014) in the Zagros forests, revealing that the progressive death of individual branches eventually affects the entire crown, marginal necrosis and chlorosis of foliage. Furthermore, the vascular discoloration of twigs and branches increase their susceptibility to biotic agents, sucking insects and diseases (pathogenic fungi or insect pests), which might overpower the weakened stand and tree death (Jozeyan, 2015) (Figure 3).

3.2. Monitoring Dieback Rate

In order to evaluate the effects of treatments on mortality trends and rehabilitation, inventory of both healthy and dieback trees was carried out within each plot twice a year during the research time. The findings indicate that *Quercus persica (Q. persica*) is a prevalent species in Zagros forest stand while *Cerasus microcarpa* is a marginal species, both of which are affected by dieback event. The inventories of all the stands at plot scale (after implementation of plots and before constructions of trenches in September, 2012) are presented in Table 1. These results implied that the average tree density in each plot was 63 trees (92.7% oak), of which 28 individuals were stands (44.5 % forest stand) affected by drought-driven dieback (Table 1).

Fig. 3. Progressive death of individual oak forest (*Quercus persica*; A and B) and their susceptibility to pathogenic fungi or insect pests (C and D)

Table 1. Forest dieback rate at beginning the research work (September 2012)

treatment*	replication (plot)	tree species			
		Quercus sp.		*Cratagus sp.*	
		dieback	healthy	dieback	healthy
T+PT	A_1	33	37	2	4
	A_2	20	36	1	1
	A_3	19	32	3	1
PT	B_1	36	29	3	6
	B_2	30	35	3	4
	B_3	20	17	-	3
T-PT	C_1	42	65	1	3
	C_2	34	48	2	4
	C_3	23	25	-	2
CT	D_1	19	27	2	2
	D_2	23	33	1	2
	D_3	12	13	-	1

***T+PT = Trench + Protection Treatment, PT= Protection Treatment, T-PT = Trench without Protection Treatment and CT= Control Treatment

3.3. Rainfall Deficiency and Volumetric Runoff Harvesting

As shown in Table 2, the average annual precipitation and temperature had been adversely changed by the effect of recent drought leading to forest mortality. Accordingly, the annual precipitation deficit is -81.3 mm (about 18%) occurring mainly in winter. In contrast, the average of annual temperature has increased from 15.2 to 16.3 ºC (+1.1 ºC) indicating a higher level in both spring and summer seasons. Moreover, the annual average of frozen days has fallen (~8 days). Furthermore, volumetric stored runoff by MCRH measure regarding rainfall deficit has been caused by drought wave (-81.3 mm) estimated as following:

- Runoff coefficient 36% (15 % slope, clay loam soil and semiarid forest);
- It is evaluated that less than 85% of the runoff was captured and infiltrated in the soil depth by trenches measured;
- Rainfall shortage during recent drought event: 440 – 81.3= 358.7 mm;

- Runoff volume (from 358.7 mm) =129.2 mm; and
- Stored runoff via MCRH in the soil depth (85% of all runoff) = 1098.2 m^3ha^{-1}

Table 2. Changes in the average rainfall and temperature during severe Zagros forest mortality and drought occurrence in the study area

year		spring		summer		autumn		winter		frozen days	annual	
		rain. (mm)	tem. (°c)	rain. (mm)	tem. (°c)	rain. (mm)	tem. (°c)	rain. (mm)	tem. (°c)		rain. (mm)	tem. (°c)
2010-11		133.3	18.0	4.2	28.2	55.8	13.5	128.0	3.5	89	342.0	16.7
2011-12		170.8	17.2	0.0	27.5	131.8	10.8	112.9	5.2	91	414.4	16.8
2012-13		53.6	18.2	0.0	27.4	179.7	13.6	132.6	4.8	92	375.9	16.4
2013-14		80.4	17.3	0.0	28.0	161.5	12.1	167.2	4.5	77	409.1	16.2
2014-15		55.6	17.1	0.0	26.7	131.1	11.8	45.6	5.2	88	252.3	15.8
2015-16		60.3	18.1	4.3	27.1	-	-	-	-	-	-	-
Ave*	6 yr	92.3	17.4	1.4	27.5	132.0	12.4	117.3	4.7	87.4	358.7	16.3
	LT	124.0	16.1	1.5	26.1	125.0	11.6	189.5	3.8	95	440.0	15.2
	Dif.	-31.7	+1.4	-0.1	+1.4	+7	+0.8	-72.2	+0.9	-7.6	-81.3	+1.1

* LT= long term, Dif. = Difference between long term and 4 yr

3.4. Soil Moisture Measurement

The statistical analyses of 99 recorded soil moisture percentages (SMP) with TDR for three soil layers are presented in Table 3. The average SMPs in the bed trench, embankment and control point were 22.7, 13.1 and 11.8%, respectively; the value in bed trench was significantly higher than that of the other points. Nevertheless, there were significant differences ($p<0.05$) among the soil moisture of the sites, as shown in Table 3. The increase in SMP was followed by soil depth. Consequently, a higher level of stored moisture (about 26%) was found within the third layer (30-50 cm) in the bed trench compared to that of the control site (7-10%). The results also revealed that SMS accumulates from the upper to lower soil layers (19, 23 and 26%), while there is an adverse trend in the control site. Therefore, as a source of needed moisture, the oak root system is immune from evaporation, for it is saved in the depth of soil layer. As a result, the enhancement of soil moisture through the trenches was twice more than that in the control point (22.7% compared to 11.8%) (Table 3).

Table 3. Soil moisture storage by crescent-shaped trench in the study site (Kalezard forest, Kermanshah, Iran)

year	sensor* depth (cm)	sample size	soil moisture content (%)			Pr > F**
			trench bed	trench edge	control plot	
2012-13	10-15	17	18.8 (a)	14.1 (ab)	11.9 (b)	0.0073
	15-30	17	22.5 (a)	12.1 (b)	11.0 (b)	<.0001
	30-50	17	25.8 (a)	8.1 (b)	7.6 (b)	0.001
	sum	51	22.4 (a)	11.3 (b)	10.0 (b)	0.002
2013-14	10-15	16	19.0 (a)	16.2 (a)	14.9 (a)	0.4085
	15-30	16	23.46 (a)	15.7 (b)	15.1 (b)	0.0453
	30-50	16	26.5 (a)	13.4 (b)	10.2 (b)	0.003
	sum	48	23.0 (a)	14.9 (b)	13.6 (b)	<.0001

*measured by TDR(equipped with connector waveguide sensor), ** Numbers followed by different letter are significantly different at p < 0.05 level

3.5. Mortality Rate Affected by Treatments

As the present study aimed to evaluate the effects of MCRHS on changing the trend of tree dieback, all the dead and vital trees were recorded twice a year within treatments. Tables 4 and 5 present the statistical analyses of all the treatments. Their mortality and re-growing rates are as following:

Trench with Protection Treatment (T+PT): the average of dieback trees per plot area in first (2012-13), second and third year were 26.0, 26.6 and 23.2 tree/1500 m^2, respectively (25.0, 22.5 and 21.2%, from all trees). Furthermore, as given in Table 5, T+PT also attributed to re-growing of some dried trees. This rate was three trees per plot (18 tree ha^{-1}). The total saved trees including mortality-reduced and re-grew ones, by T+PT treatment was 55.7 ha^{-1} trees in the forest stand. Accordingly, both the reduction of mortality rate and re-growth of dried trees are the two main positive effects demonstrated by CST+P measure. Field verification showed that the root system of re-vegetated stands is not infested by pest and the disease is mainly located in the nearest downward trenches (Figure 4).

Protection Treatment (PT): the average of dieback trees per plot area in the first, second and third years were 31.7, 33.5 and 31.5 tree/1500 m^2, respectively. The ratios of dead trees to all the stands were 31, 28 and 28%, respectively. According to Table 5, the treatment did not affect the re-growth, which contributed to the reduction of dieback severity (37.7 trees ha-1) as compared to the control treatment. However, PT helped protect 38 trees ha^{-1} from drying whereas it was not effective on the re-growth. This combats moisture depletion through tillage practice, overgrazing, arson fire and forest clearance. Thus, the effect of this treatment was found to be lower than CSB+P (37 compared to 56 trees ha^{-1}).

Trench without Protection Treatment (T-PT): the ratios of the dried trees in the first, second and third years were respectively 25.8, 35.7 and 37.8 tree/1500 m^2, indicating lower efficiency of T-PT treatment on mortality reduction compared to the control plots. The reduction of dieback rate was 6 tree ha^{-1} compared to the control plot revealing the importance of protection which is crucial for the protection of built trenches, the decrease in the negative effects of anthropogenic deforestation, and soil degradation at local scales, mainly grazing and tillage practices. By and large, forest protection is a measure of great necessity, which should be carried out to boost the effects of runoff harvesting for cordial drought effects on forests.

Control Treatment (CT): The ratios of the dried trees in the first, second and third years were respectively 26.0, 26.6 and 23.2 tree/1500 m^2, indicating the fast mortality rate of Zagros forest along the time. The average increase in the dieback rate was 36.7 tree ha^{-1}. Obviously, dieback severity in Zagros forest has been intensified by the current human-induced soil disturbance and deforestation activities and their impacts (Tables 4 and 5).

Table 4. Annual forest dieback changes over time affected by the treatments in the study site (Kalezard forest, Kermanshah, Iran)

year	forest tree	treatment (tree/1500 m^2)				Pr > F*
		T+PT	PT	T-PT	CT	
2012-13	dieback	26.0 (a)	31.7 (a)	28.7 (a)	19.6 (b)	0.0165
	healthy	37.0 (ba)	30.5 (b)	54.3 (a)	25.7 (b)	0.0217
2013-14	dieback	26.6 (ab)	33.5 (a)	30.5 (a)	22.0 (b)	0.0245
	healthy	36.0 (ba)	28.7 (b)	50.6 (a)	23.4 (b)	0.0210
2014-15	dieback	23.2 (b)	31.5 (a)	33.3 (a)	25.1 (b)	0.0360
	healthy	38.7 (ba)	30.0 (b)	49.7 (a)	21.4(b)	0.0151
Average	dieback	25.27 (ab)	32.23 (a)	30.84 (a)	22.23 (b)	0.0130
	healthy	37.23 (ba)	29.73 (b)	51.53 (a)	23.5 (b)	0.0133

* Numbers followed by different letter are significantly different at $p < 0.05$ level

Table 5. Re-vegetation of dried tree and reduction in dieback rate through treatments in the study site (Kalezard forest, Kermanshah, Iran) from 2012-13 to 2014-15

treatment	re-vegetation of dried tree		reduction in dieback rate*		total (ha)
	average change/ plot (1500 m^2)	ha	average change/ plot (1500 m^2)	ha	
T+PT	3	19	5.5	36.7	55.7
PT	-	-	5.7	38.0	38.0
T-PT	-	-	0.9	6.0	6.0
CT	-	-	-5.5	36.7	36.7

* compared to control treatment (CT)

5. Discussion

The diagnostic characteristics of dieback event in Zagros forest, which has been observed since 2000 (Hosseini, 2014; Attarod *et al*., 2015), are almost the same in the United States and Europe as reported by Thomas and Büttner (1998) and Ciesla and Donaubauer (2006). Furthermore, aassessment of regeneration (coppice, high stand and both) reveals 95% of oak coppice types regeneration. Thus, rare sexual regeneration in the region is a result of human-induced deforestation, mainly livestock grazing and tillage practice. Recent researches about oak regeneration in Zagros have illustrated that seed originated (sexual) regeneration is limited in mixed coppice with high stand of oak type mostly spread out on the north faced slopes (Soleymani *et al.* (2012).

Stands with a high level of mortality over a short time period will have a relatively quick change in soil moisture (Assal, *et al.*, 2016) and subsequently, heightening dieback rate mainly due to aggravation of climate change impacts by other anthropogenic stresses, such as fragmentation, deposition or habitat destruction practices (Milad *et al*., 2011).

The change in the tree dieback rates through the treatments are shown in Table 5. The total restored trees and reduced trend in mortality rate by T+PT treatment is 19 and 36.7 tree ha^{-1}, respectively. In contrast, the reduction of 38.0 tree ha^{-1} in dieback occurred by PT treatment. Finally, the effect of B-PT treatment on Zagros forest mortality was found to be lower compared to that of other treatments mainly due to human-induced soil disturbance leading to soil moisture and loss of nutrients.

The extensive oak decline occurs on dry and nutrient-deficient soils (Kabrick *et al*., 2008) while runoff harvesting system enhances the efficiency of nutrient by conserving the soil and water (García-Avalos *et al*., 2018). During the research, it turned out that the forest trees under T+PT treatment faced a significant reduction ($P<0.05$) not only in mortality trend, but also in the restoring. However, PT just reduced the dieback rate. In addition, T-PT is considered as a weak treatment to combat Zagros forest dieback; accordingly, no significant effects were observed on forest mortality applying this treatment. The significantly lower effect of T-PT treatment on soil moisture storage could be mainly associated with the soil disturbance factors, for instance tillage practice, grazing, fire and logging. These factors make the sealing and crusting on the surface of soil and lead to failure in infiltration and intensification of evaporation. The smectite is a dominant clay mineral in both soil and parent material in the study area and most parts of Zagros area (Heshmati, *et al*., 2011; Zhang, 2013), which is more susceptible to dispersion of soil aggregate, seal formation, runoff and soil loss (Lado *et al*., 2004).

Therefore, B+PT is of two dimensional effects, including restoration of some dead trees and curtailing forest mortality event. The obtained results revealed that trench construction should be performed by protection measure since it could only combat 11% of mortality without protection compared to T+PT treatment. It could be seen that a higher value of restoration is found for T+PT compared to the other treatments (Figure 4).

Fig. 4. The effects of built trenches after three years: vital forest tree (A and B); re-vegetation of dried branches (C) and re-growing the dried stand (D)

In fact, the protection treatment effect on forest mortality is intermediate. As a result, micro-catchment and protection has a significantly positive effect on forest restoration combating trees drying through soil moisture retention. Therefore, since stored moisture is a crucial source of forest survival, the rainwater harvesting is a viable option for the adaption of these forests with current climate changes. Nevertheless, T+PT and PT treatments are the respective faire measures behind the adaptation, which needs to overcome the negative impacts of climate changes on Zagros forest and other similar environmental areas. However, our priority should go to taking certain measures to promote water and soil conservation (Iglesias and Garrote, 2015).

As indicated by Allen *et al.* (2010), the climate changes raise concern that forests may become increasingly vulnerable to higher background tree mortality. So far, there has been no signs showing the ability of trees to adapt to climate changes. Consequently, in semiarid regions, runoff utility is more seriously considered by experts and researchers (Chmura *et al*., 2011). Ultimately, this adaptive measure is suggested to be developed and tested at a landscape pilot in the Zagros or other similar forest areas evaluating their several aspects. The aattempts concerning adaptive management for biodiversity may be improved by better collaboration and better communication with relevant managers. (Westgate *et al*., 2013).

6. Conclusions

The forest mortality triggered by climate changes has spread throughout Zagros areas indicating the urgent need for short term implementation to reduce soil moisture deficit by runoff harvesting. We evaluated the effects of crescent shaped trenches as an adapted micro-catchment runoff harvesting system (MCRHS) on mitigation of the forest mortality induced by climate changes. As a result, we found that this measure is an environmental sound combating forest episode induced by the failure of seasonal precipitation and drought stress. Therefore, this technique will undoubtedly be expanded in similar ecosystems, but with appropriate adoption practices. However, our findings demonstrated significant trends in the restoration of dieback forest applying T+PT treatment. Thus, it is considered as a dominant related measure. To this end, the results exhibited that the favorable restoration of some dead trees occurred just under T+PT treatment. Furthermore, protection is also necessary for trench construction, which restricts the livestock access and exploitation of local people providing favorable conditions for embedding effects of runoff, in order to reduce soil disturbance and deforestation agents. Without long-term solutions, however, T+PT is a simple, economic and short-term effective measure for soil moisture enhancement with the minimum soil disturbance mitigating the dieback tendency, which could be adapted for Zagros forests, Iran.

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