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Effects of Converting Grassland to Rainfed Areas on Soil Nutrients and Plant Growth

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ABSTRACT

Aim: Land use change (LUC) affects the plant and soil functional properties and influences soil nutrients efficiency. This research was carried out to examine the effect of grassland conversion to dry farming on the efficiency of bio-mineral nutrients in semi-arid loamy soils of northwestern Iran.

Materials & methods: Animal manure (AM: 100 and 200 g. Kg^{-1}), beneficial micro-organisms (UMOs: 1 and 2%), superabsorbent polymers (SAP: 10 and 30 g. Kg^{-1}), and potassium nano-silicate (PNS: 500 and 1000 mg. Kg^{-1}) were used for grass *Festuca ovina* L. cultivated in grassland and dry farming soil at a completely randomized factorial design.

Findings: Based on the results, LUC strongly affected the efficiency of soil nutrients, especially PNS ($P \leq 0.01$), where the highest and lowest effects of different nutrients were observed under dry farming and grassland, respectively. A maximum difference of 24.0%, 45.0%, and 24.0% was observed in plant biomass, chlorophyll, moisture content, respectively, using 200 g. Kg^{-1} AM and 30 g. Kg^{-1} SAP in the soil of grassland and dry farming. Also, a maximum difference of 71.0% and 67.0% occurred at soil phosphorus and organic matter, respectively, between grassland and dry farming. Depending on the type and amount of fertilizer, converting the grasslands to rainfed areas significantly influences plant performance and soil improvement. Overall, grasslands show a better performance due to the undisturbed soil than rainfed areas under any rehabilitation program.

Keywords: Biological fertilizer, *Festuca ovina*, Mineral fertilizer, Potassium nano-silicate, Superabsorbent polymers.

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Introduction

land-use change (LUC) severely affects soil nutrients and plant growth. In general, LUC under anthropogenic activities drives global environmental change and sustainable development of ecosystems [1–4]. In the global issue, convert grasslands to rainfed areas is one of the world's whispered LUC [5,6] the efforts to manage ecosystem services have increased. One such tool to help manage ecosystem services is the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST. On the one hand, LUC has a direct and significant impact on ecosystems function [7,8] and strongly affects soil performance, i.e., the maximum biomass production and environmental sustainability [9].

Due to the changes in soil physicochemical properties, soil can be destroyed under LUC [10], and the magnitude of LUC and its assessments vary with the period being examined and the geographical area [11]. Moreover, human-induced changes in LUC play a significant role in the ecological function of the earth [2], where soil and vegetation are severely influenced under LUC [12]. Therefore, inappropriate land use is one of the main reasons for soil loss [13] and vegetation change[14]. Cropping in rainfed areas exposes the land to erosion risks, and eroded land will eventually have poor productivity [15].

Significant differences in many of the soil properties have been reported under LUC [12,16]. Along with changes in soil and vegetation types, the efficiency of different soil nutrients can be strongly influenced through LUC. Nevertheless, there is no exact information about these changes under long-term change of grassland to rainfed areas. Using nutrients is one of the most important management practices for sustainable production of land that influences soil/plant and sustainable land-use systems, and therefore, is needed to maintain soil fertility for plant production [17]. In grassland and cropland, however, many different soil nutrients, i.e., mineral, biological, in/organic, and nano fertilizers, are used to increase production. However, the efficiency of the nutrients may be strongly influenced by LUC [18].

The use of nutrients is a costly method and should be noted in any rehabilitation program. However, depending on the type of nutrients and environmental conditions, their efficiency may be severely affected by land use. The main hypothesis of the present study is that depending on the type and amount of nutrients used, convert the grasslands to rainfed areas will significantly change the soil properties and physiological properties of plants. The research results are valuable for land management, especially in the long run. Therefore, the main objective of this study was to investigate the effect of bio-mineral nutrients; animal manure (AM), beneficial micro-organisms (UMOs), superabsorbent polymers (SAP), and potassium nano-silicate (PNS) on the growth properties of *Festuca ovina* and soil properties under converting grassland to a rainfed in Ardabil boozer's semi-arid rangelands, northwestern Iran.

Materials and Methods

Study area

The study was done in the research field of the University of Mohaghegh Ardabili, in northwestern Iran. The study site is located in semi-arid rangelands, where a large area of the rangelands have been converted to rainfed since 2005. The area lies between 37°51′N and 47°45′ E longitude and 38°22′N and 48°23′ E latitude covering approximately 1058 km^2. Its altitude ranges from 1150 to 4811 m above sea level. Mean annual rainfall and temperature is 500 mm and 5.9℃, respectively. The mean monthly temperatures vary from 3.9 °C in August to 7.9 °C in April. The topography of the area is typical of mountains and plain. The area is covered by both annual and perennial species.

In converted lands, rainfed cultivation is done every year. In recent years, chemical fertilizers have also been used in some rainfed areas. Nevertheless, no nutrient has been used in the study site so far. Grass Festuca. ovina. L mainly covers the control area. The natural cover in the control area is managed without any intervention and only through livestock grazing. Thus, two adjacent sites were examined for the experiment under two land-use of grassland and rainfed. The research was performed based on design 72 (36 in grassland and 36 in dryfarming= 9 types and concentration of nutrients × 4 replication) plots (0.5×0.5 m) in two consecutive years of 2018-2019 [14].

Study species

F. ovina L. (English name: Sheep's-fescue) was selected for an experiment with perennial and native grass in this area. This plant is suitable for grazing [19], which is used in seed mixes intended for turfing nutrient-poor soils and sowing in slopes, roadsides, car parks, and restoration areas due to having a well-developed root. The primary usage of *F. ovina* usage is for cultivation as forage in rangelands revegetation programs[20].

Soil properties

The research was performed based on placed 72 plots in two adjacent sites. Soil sampling was taken based on the random systematic method in plots. The depth of sampling was selected according to plowing depth for cereal cultivation in rainfed areas. Therefore, samples were taken in 0-30 cm of soil layers in the dry farming land and grassland. Soil samples were transferred to the laboratory and were prepared for analysis. Before the experiment and nutrients application, the soil physicochemical properties were investigated for two sites. Soil properties included pH (using Swiss Metrom 826 pH meter apparatus), EC (using PET 103 EC meter), organic matter (OM), phosphorus (P) (using Hach model dr2800 spectrophotometer), and potassium (K) (Using soil potassium filimeter) were measured (Table 1).

Table 1) Physiochemical properties of soil in two land uses

Soil factor	Grassland	Dry farming
Sand (%)	55.95 ± 8.05^{B}	$62.80\pm3.25^{A*}$
Silt (%)	21.19 ± 4.42^{A}	20.60 ± 9.13^{Ans}
Clay (%)	24.68 ± 4.22^{B}	$17.66\pm6.25^{A*}$
pH	7.55 ± 0.40^{B}	$8.13\pm0.15^{A*}$
EC ($ds.m^{-1}$)	1.12 ± 0.12^{A}	$0.78\pm0.10^{B*}$
P ($Mg.Kg^{-1}$)	29.41 ± 5.12^{A}	21.4 ± 4.42^{Ans}
$CaCO_3$ (%)	17.17 ± 4.33^{A}	16.73 ± 5.21^{Ans}
OM (%)	1.91 ± 0.68^{A}	$1.03\pm0.43^{B*}$
K ($Mg.Kg^{-1}$)	429.13 ± 25.08^{A}	$371.73\pm32.55^{A**}$

**: Significant at 1% confidence, *: Significant at 1% confidence, ns: Not significant. Similar letters had no significant difference at first and second soil layers (p≤0.05)

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Treatments used in the research

Mineral, biological, organic, and nano treatments including animal manure (AM), beneficial micro-organisms (UMOs), superabsorbent polymers (SAP), and potassium nano-silicate (PNS) were used for the experiment.

Pars Emkan-Pazir Company, Iran, prepared material for UMOs. UMO comprises water, sugar molasses, aloe vera, photosynthetic bacteria, lactic acid bacteria, and yeast. The number of effective UMOs components was 120. The decayed AM used in this experiment was obtained from the farm of the University of Mohaghegh Ardabili. AM moisture content = 13%, EC=40ds.m^{-1}, pH=7.6, SP=75.1%, OC=5.3%, K=230, P= 23. The PNS was purchased from Sigma Aldrich Company and was prepared by Mina Tajhiz Aria. PNS was a white powder in form with a particle size of 1200 nm. PNS properties are presented in Table 2. The SEM image of PNS is shown in Figure 1.

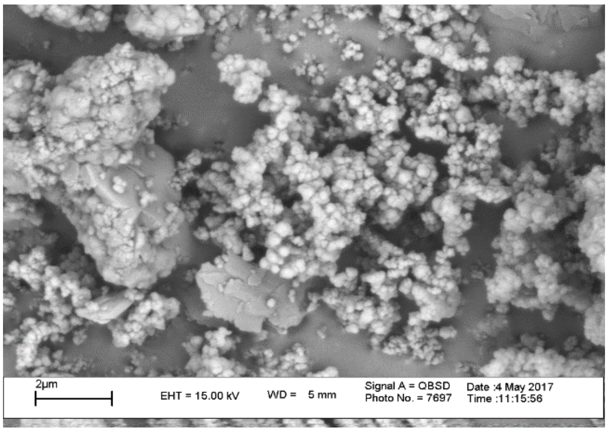

Figure 1) Electron microscopy of PNS

SAP has no bad and harmful effect on humans, plants life, and the environment and absorbs water and then gradually gives back to the environment [21], which resulted in more water and nutrients availability in dry environments to reduce the effects of water scarcity [22]. The SAP was obtained from Shirvan Crystal Water Company. It was brown powders with a particle diameter of 200–400 µm, with concentrations of 0, 10, and 30 g.kg^{-1} added to the soil. The properties of SAP are shown in Table 1.

Plant cultivation and treatments application

Seeds of *F. ovina* were obtained from the Pakan Bazar Isfahan Company with purity percent of 95%, germination of 90-100%, and 1000 seed weight of 0.9 gr. The experiment was conducted in a factorial experiment in randomized complete block design using 2 types of grassland soils and rainfed, applying 4 nutrients with 4 replications in plots. Treatments were included AM fertilization (at three levels of 0, 100 and 200 g.kg^{-1}), UMOs (levels of 0, 1 and 2%), SAP (levels of 0, 10 and 30 g.kg^{-1}), PNS (levels of 0, 500 and 1000 mg.kg^{-1}). The required amount of each nutrient was determined based on the density and volume of soil for 30 cm depth in the plot. For the application of treatments, SAP and AM were mixed with soil at two levels at the time of cultivation at spring and added to plots according to the experimental design. Thirty seeds of *F. ovina* were planted in each plot at a depth of about 1-2 centimeters in treated soil with SAP and AM treatments. In addition, for treatments of PNS and UMOs, the seeds were sown in untreated soil and, then the treatments were applied. In order to eliminate the effect of drought stress and to better understand the effects of treatments on plant performance, irrigation periods were used. The experimental plots were irrigated continuously based on field capacity. Then, after the seeds were germinated at the four-leaf stage, PNS was added to the plots at concentrations of 500 and 1000 mg.l^{-1}. Adding the PNS was done twice a week until the end of the experiment.

Also, UMOs solution with 1 and 2% concentrations was added to plots three times until the end of the growth period

Table 2) The properties of PNS and SAP used in the experiment (Source; Shirvan Crystal Water and Sigma Aldrich Company claim for PNS and SAP, respectively)

SAP		PNS	
Properties	Rate	Properties	Rate
Shape form	Brown powder	Molar mass	84.9947 ($g.l^{-1}$)
Amount of moisture	<5	Shape form	White powder or crystal
Smell and toxicity	-	Density	2.225 $g.cm^{-3}$ (16 in Celsius)
Average mass density ($g.cm^{-3}$)	0.8	Melting point	380 Celsius
pH water solution	6-7	Boiling point	380 Celsius
Particle Size (micrometer)	200-400	Fracture coefficient	1.587 Rembouheral
water absorption capacity (Equilibrium absorption) ($g.g^{-1}$)	500	Solubility in water	730 $g.l^{-1}$ (0 ºC) 921 $g.l^{-1}$ (25 ºC) 1800 $g.l^{-1}$ (100 ºC)
		Specific heat capacity	95.06 Jules On Mole Kelvin
		Particle Size (nm)	1200

(UMOs was added in three stages since the plant had four leaves), with 10 days interval. After seed germination and growth, timely control of diseases, pests, and general conditions was carried out. The first irrigation was done on the same day, and the plots were irrigated during the experiment. The experiment lasted 6 months until the end of the summer.

Measuring plant and soil properties

Plant properties were measured two times through 2 years of experiment. In the first year, after 6 months (September), plant growth properties of chlorophyll index (measured by chlorophyllometer model 502 PLUSSPAD, made in Japan), leaf area index (measured by a leaf surface gauge model; Delta MK_2) plant biomass was measured. In the second year, vegetative properties and root length, biomass, and moisture were measured. Also, at the end of the experiment, soil physicochemical properties in experimental plots was measured again.

Statistical analysis

The data were checked for normality using the Kolmogorov-Smirnov test. ANOVA and Duncan tests were used to compare soil and plant growth results under different bio-mineral nutrient treatments. T-test also was performed between grassland and rainfed data. The data analysis was performed using statistical SPSS ver: 17.01 software, and graphs were designed in excel software.

Findings

Effect of LUC on nutrients efficiency

The combined analysis of variance showed the effects of UMOs, PNS, SAP, and AM treatments under soil grassland and rainfed area on growth indices of the plant. At first, plant height and biomass significantly changed under different soil nutrients. However, the most crucial change was observed under two land use at a 1% probability level. Using PNS (L;1000 $mg.kg^{-1}$), plant height increased 35 and 101% in

Table 3) Statistical analysis for soil and plant properties under different bio-mineral nutrients in two soil types

	Soil properties			Plant properties		
Variable	SOV	MS	F	SOV	MS	F
Soil type	pH	0.35	1.18 ns	PH	29.0	2.35 ns
	EC	32396.15	79.24 **	AB	66.06	3.12 **
	OM (%)	212.21	92.12 **	AMC	51975.66	15.44 **
	P (ppm)	1.41	6.37 *	RB	1540.21	45.395 **
	K (ppm)	20612.39	26.55 **	RL	547.19	8.886 **
	-	-	-	RMC	2163.08	47.634 **
	-	-	-	LAI	55.12	2.364 *
	-	-	-	Chl	31.07	1.238 ns
Fertilizes	pH	0.49	1.35 ns	PH	48.75	3.95 **
	EC	27627.47	67.58 **	AB	13.47	6.95 **
	OM (%)	327.25	142.06 **	AMC	51849.06	6.55 **
	P (ppm)	12.07	3.36 *	RB	241.28	4.25 **
	K (ppm)	51491.94	66.39 **	RL	305.39	4.95 **
	-	-	-	RMC	2524.63	5.00 **
	-	-	-	LAI	48.83	2.09 **
	-	-	-	Chl	92.21	3.67 **
Soil type* Fertilizes	pH	0.72	1.94 ns	PH	36.80	2.98 *
	EC	2938.29	7.18 **	AB	10.71	5.52 **
	OM (%)	70.00	30.39 **	AMC	30628.10	3.99 **
	P (ppm)	7.10	1.90 ns	RB	208.29	3.67 **
	K (ppm)	11943.40	15.40 **	RL	227.82	3.70 **
	-	-	-	RMC	1507.46	2.39 *
	-	-	-	LAI	23.89	1.02 ns
	-	-	-	Chl	30.51	1.21 ns

rainfed areas and grassland soil, respectively. In addition, plant biomass under SAP (L;30 g.kg^{-1}) application showed an increase of 23 and 67% in the rainfed area and grassland soil, respectively (Figure 2).

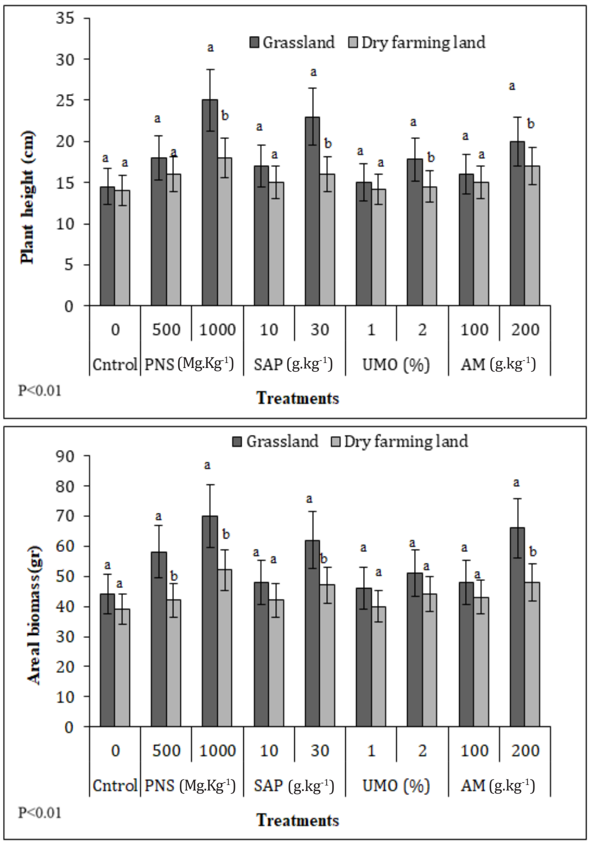

Figure 2) Effect of different nutrients on plant height and areal biomass in grassland and dry farming (comparisons were made in pairs for each treatment with a specific concentration)

A comparison of plant chlorophyll cultivated in rainfed areas and grassland under nutrients treatments showed different results. Figure 3 showed that the highest chlorophyll content was related to SAP treatment with a concentration of 30 g.Kg^{-1}. However, soil type had a significant effect and increased chlorophyll from 4 and 3.6 to 11.9 and 9.0 in the soil of grassland and rainfed areas, respectively. There was a difference of 32% in chlorophyll content in plants under two types of soils. Moreover, the leaf area index showed a similar change under different treatments, even UMOs at two levels also had a positive effect, and the most change was observed in the soil of grassland (Figure 3).

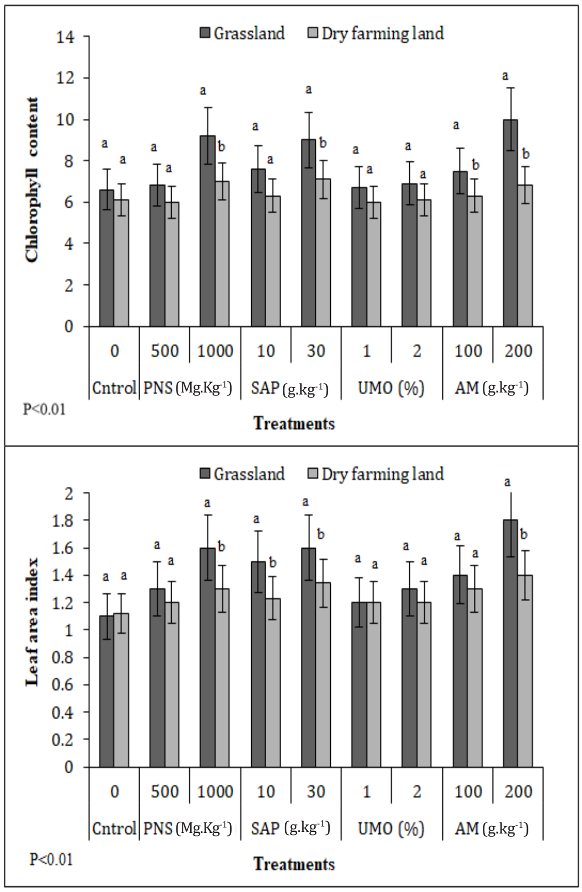

Figure 3) Changes in plant chlorophyll and leaf area index under land-use change and different nutrients.

Also, root length and biomass showed significant differences (*P<0.01*) concerning different nutrients under two soil types. Although different nutrients influenced root properties, the soil of land use type significantly changed root length and biomass. Generally, root length fluctuated, and the maximum length was observed in the soil of the rainfed area under PNS (1000 mg.Kg^{-1}). However, the maximum root biomass was observed in the soil of grassland under SAP (30 g.Kg^{-1}) treatment. Type of soil had a maximum effect of 66% in SAP treatment. AM (200 g.kg^{-1}) also significantly increased root biomass (46%), particularly in the soil of grassland (Figure 4).

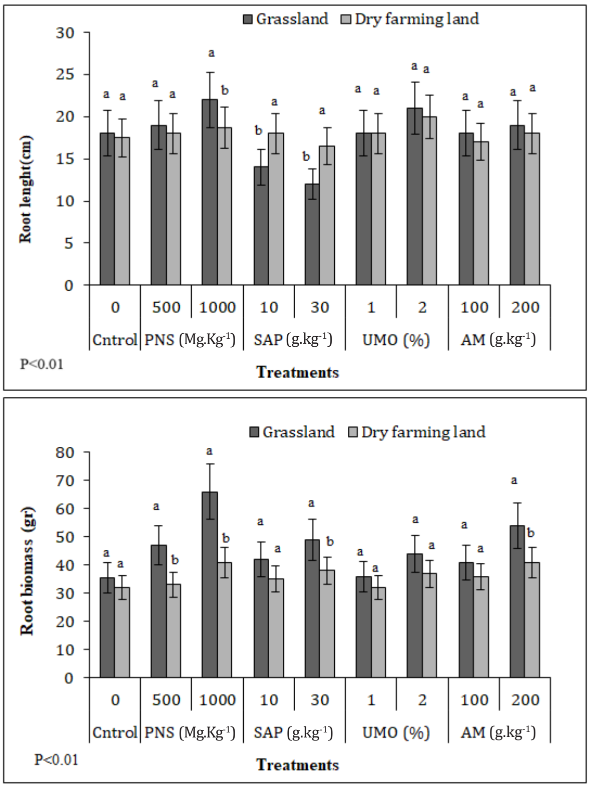

Figure 4) Changes in root length and biomass concerning different nutrients under two soil types.

The moisture content of plant areal parts and roots showed differences under different bio-mineral nutrients in the soil of grassland and rainfed areas. Generally, SAP treatment had the most positive effect on the moisture content of plant areal parts and roots.

However, in areal parts, the highest value was observed under SAP-30g.Kg^{-1}, in which grassland significantly increased moisture content from 36.0% to 46.0% concerning rainfed area (35.5% to 40.0%). Different nutrients had a positive effect on moisture content, but the effect of rainfed and grassland soil was more noticeable (Figure 5).

Effect of nutrients on soil properties under LUC

Comparing soil factors under treatments showed that UMOs, PNS, SAP, and AM had positive and significant effects on soil EC, OM and K except for pH (P<0.01). However, grassland and rainfed areas lead to a significant change in soil properties in which the most positive changes occurred in the soil of grassland (Table 3).

SOV= Source of variations, MS= Mean Square, PH= Plant height, AB= Areal biomass, AMC= Areal moisture content, RB= Root biomass, RL= Root length, RMC= Root moisture content, LAI= Leaf area index, Chl= Chlorophyll.

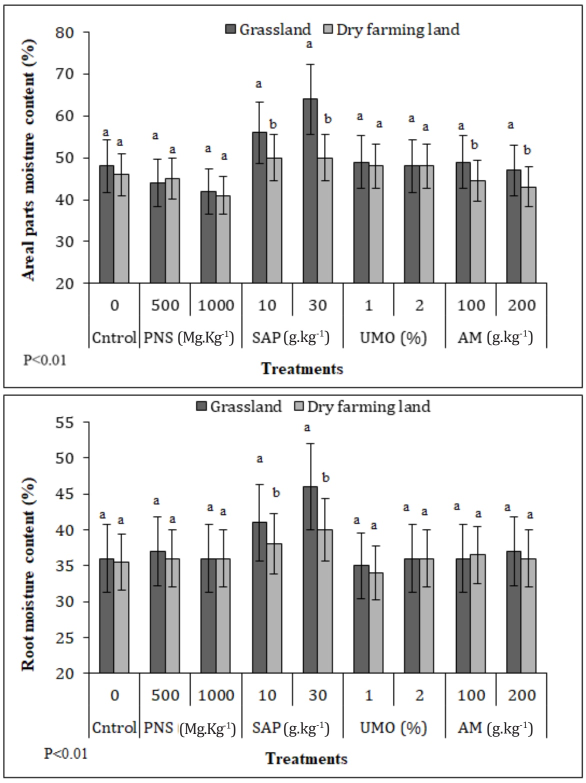

Figure 5) Changes in moisture content of plant areal parts and roots with different nutrients and different land uses

Although soil pH changed under different treatments, there was no significant difference between different nutrients and control at 1%. Results showed that the highest value occurred under PNS treatment with 500 mg.Kg^{-1} concentration in grassland and the lowest amount was obtained in AM treatment (200 g.Kg^{-1}) under rainfed areas. In addition, the results of treatments on EC showed that the highest amount occurred under AM (200 g.Kg^{-1}) in grassland, and the lowest amount was for 500 mg.kg^{-1} of PNS treatment in grassland (Table 3, Figure 6). Depending on the soil texture, excessive

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water in the soil dilutes the solute concentration and decreases the electrical conductivity of the soil. As a result, as the amount of SAP in the soil increases, the EC decreases, which is inconsistent with the results of our research.

The effect of treatments on organic matter content showed that the highest amount was related to AM of 200 $g.kg^{-1}$ under grassland and the lowest amount was for SAP (L1 and L2) in rainfed areas. Moreover, the effect of treatments on soil K showed that the highest amount was related to AM (concentration of 200 $g.kg^{-1}$) under grassland and the lowest amount was for UMOs treatment at a concentration of 1% under rainfed. P content also changes under different nutrients. However, the soil type of grassland had the most positive effect on P (Figure 6).

Discussion

Based on the results, using bio-mineral nutrients, LUC showed different effects on soil and plant properties. PNS had positive effects on the plant height, chlorophyll, areal parts, and root biomass. It seems that potassium availability in the soil leads to an increase in the efficiency of plants in nutrient uptake, and more performance will result. Similarly, the significant and positive effects of NPs on plant physio-morphological, including chlorophyll content, root length, and plant biomass, have been reported by Abad et al. and Clément et al. [23,24]. Generally, PNs application increases plant resistance to diseases, pests, and stresses [25] and improves plant enzyme activity and its biomass [26]. However, in this study, using PNS, plants cultivated in grassland soil showed higher

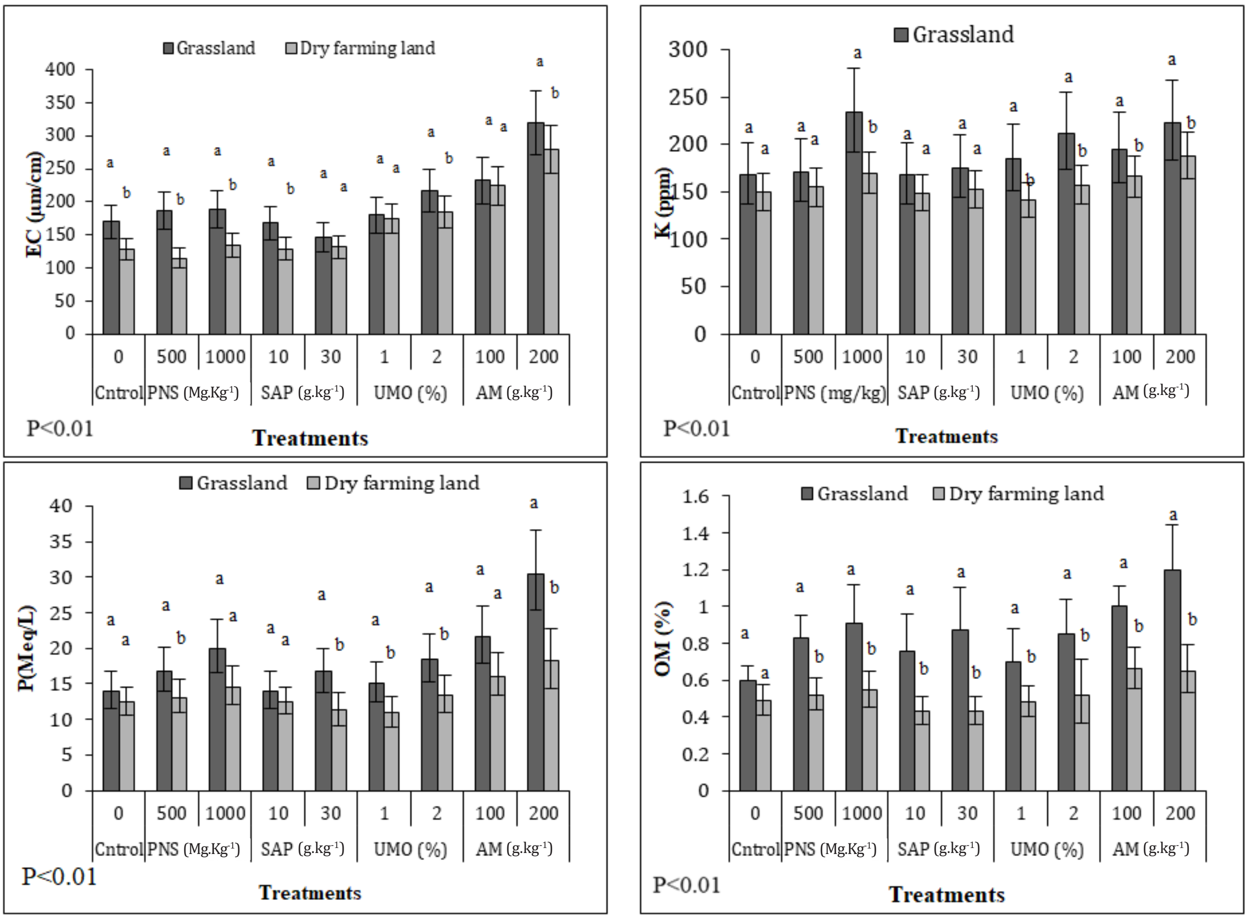

Figure 6) Change in soil EC, P, K, and OM under different nutrients and land use (Comparisons were made in pairs for each treatment with a specific concentration)

performance than rainfed areas. PNs could be used to improve the establishment and growth of plant species in rangeland restoration projects [42, 43, 44, 45]. However, the maximum improvement will happen in natural lands with minimum LUC.

Using SAP, almost all plant properties, i.e., chlorophyll and biomass, significantly changed. The maximum increase in plant properties occurred under grassland use. Generally, it seems that SAP acts as a small water tanker due to its ability to absorb large amounts of water and leads to improve plant properties and performance [22, 28-30]. The SAP solutions also prevent the leaching of nutrients from the roots and, therefore, create a suitable condition to increase the photosynthetic material transfer and improve plants' establishment, viability, and productivity [46,47,48,49, 50, 51, 52], especially in harsh environments [47]. The conversion of natural lands destroys the soil structure, and under these conditions, the maximum efficiency of SAP will not be achieved.

Moreover, the increase in leaf area and other plant growth indices under UMOs application could be profound effects of growth regulators synthesized and promote the ability to utilize nutrients in the soil optimally. Therefore, the lowest values were related to plants cultivated in the soil of rainfed areas. The UMOs improve the process of nutrition movement, absorb the elements [31], and positively affect the establishments and performance of plants under environmental stress conditions [32–34, 53]. The UMOs application is one of the alternatives of nutrient supply methods in the soil through biological activities, resulting in more plant performance [35–38, 54]. However, though using UMOs, the maximum improvement in plant properties, especially in root length and leaf area index, was observed in grassland soil. It seems that the performance of the soil microbial community can be severely affected under LUC. Therefore, rainfed land use may interfere with the biological components of the soil through the effect of tillage on soil micro-organisms [18].

The AM application also had positive effects on plant properties and performance, confirmed Naseri et al. and Marschner et al. [38,39]. The AM can improve soil quality, increase plant yield and nutrients to extreme environmental conditions [40]. It seems that AM application improves soil condition in terms of water and nutrition availability and leads to more performance in *F. ovina*. Similar to this finding, Rezae et al. [41] reported a positive effect of AM on plant weight and performance in different species. Anwar et al.[42] also, it mentioned that AM improves soil physical conditions, provides suitable bedding for root growth, and increases plant access to nutrients. Therefore, the maximum improvement occurs in soils with minimal disturbance in which cultivated plants in grassland soil showed the maximum changes.

Soil properties also showed significant changes under both nutrients and LUC. Based on the results, the efficiency of different nutrients on soil properties depends strongly on the soil of land use. The factors of K, P, OM, EC, and pH showed fluctuations under different treatments. Generally, under grassland conditions, the positive changes in soil properties were more than in rainfed areas.

Under LUC, continuous conventional tillage can adversely affect soil physical attributes such as bulk density and texture, influencing critical functions such as water infiltration[43-47]. Therefore, it seems that at first, LUC can cause a significant change in soil physical properties, i.e., soil infiltration, and then influenced chemical properties, i.e., C and N [46–54]. Therefore, using different nutrients, LUC showed noticeable effects on soil properties, especially EC, and ultimately,

a minimum change in soil chemicals will change the soil conditions [57].
Zangooei et al. [57] mentioned that the use of SAP reduced the EC of the soil. Reduction of EC is because the SAP can absorb and retain many water and physiological solutions. Excessive water in the soil dilutes the solute concentration and decreases the EC of the soil. It seems that as the amount of SAP in the soil increases, the EC will decrease due to the decrease in soil ingredient concentration. Moreover, using nutrients (i.e., PNS and AM), the highest and lowest K value was related to grassland and rainfed areas, respectively. Although the application of other nutrients, i.e., AM, showed a different effect on P and K, especially in natural rangelands [58,59], this study also indicated that AM under grassland had a higher efficiency in soil properties i.e., organic matter. Our findings are consistent with the other findings of the effect of AM on soil elements in which increased nutrient use increased soil fertility [54].
Similarly, Allahdadi et al.[55] AM application increases the population of soil micro-organisms. As a result, the nutrient circulation will be done faster, and their absorption (especially phosphorus) will increase under minor disturbance. Land-use potentially impacts the soil properties, i.e., organic matter [56]. The LUC from grassland to rainfed areas increases respiration, and managed grasslands are an effective strategy for soil improvement [57], especially in lands under perennial grasses cover [58].
Soil P content also significantly changed under different nutrients under LUC. The soil under grassland had two times more P content than rainfed areas. It is well-known that under natural conditions, all types of P will change, but under LUC, only increased levels of inorganic P will occur by fertilization [59], and LUC can affect the amount of P loss [60].
In general, natural grassland can contribute to many ecosystem services to humans [27], and its convert to rainfed land is one of the vast LUC in arid and semi-arid areas [47], which is a significant driver of global environmental change and sustainable development [61-64]. The LUC increases soil functions, e.g., biosynthesis process and oxidative phosphorylation that reduces the ecosystem stability [65], and changes in native land covers for agriculture activities represent a threat to their ecological efficiency [66]. Most importantly, using any type of nutrients, including organic, inorganic, mineral, and biological nutrients, natural grassland has the highest plant performance. In this regard, comprehensive knowledge and understanding of LUC ecology are critically linked to natural and human effects on the environment for sustainable production [48,67], and administrative realignments or a refocusing of public outreach messaging might be alternative approaches to promoting grassland conservation [15].

Conclusion

According to the results of this study, LUC from grassland to rainfed areas significantly influenced the efficiency of different bio-mineral nutrients. In addition, the application of PNS, SAP, UMOs, and AM had different and significant effects on growth indices of *F. ovina* and soil properties under two land uses. The most positive change and improvement in soil and plant properties were observed in the soil of grassland. Moreover, improving a soil property (i.e., the organic matter under AM application) under LUC depends strongly on the type and amount of nutrients used.

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