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Economic Cost of Soil Nutrients Loss from Summer Rangelands of Nour-rud Watershed in North of IRAN

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ABSTRACT Water erosion causes a series of on-site as well as off-site damages and problems on natural ecosystem. These damages include soil and nutrient loss and finally loss of productivity which causes costs to the society. So, this study attempts to quantify the economic value of soil productivity conservation as one of the important functions of rangelands vegetation and its economic cost by productivity losses. The soil loss amounts were obtained from integrated Geographic Information System (GIS) and map of erosion vulnerable areas using RUSLE model. Supplementary data such as soil nutrients (NPK) valuated from the measurement plots of a portable rainfall simulator (E65). Field plots were constructed to measure soil nutrients and soil loss from different soil types with different resistance to erosion. Rainfall simulation was carried out in three sites on the basis of geology map and different resistance to erosion. Nine experimental unit plots (1*1 m) were used to correlate nutrient loss to sediment losses. Assuming that nutrient loss by erosion could be replaced by fertilizers, economic cost of major nutrients estimated by market prices of fertilizers. Results showed that mean annual soil loss using RUSLE was 27.44 t ha^{-1} y^{-1} ranging from 0.0 to 996.06 t ha^{-1} y^{-1}. Also, 114.17 kg ha^{-1} y^{-1} of N, P, K elements were lost in 2010 due to soil erosion in the degraded rangelands which costs (738944 Rial) 71.5 US\$ $ha^{-1}y^{-1}$. Total economic cost of soil nutrient loss in 94978.6 ha of the rangelands of Nour-rud watershed basin, was estimated $70\times10^{\wedge}9$ Rial (6.8×10^6 US\$). The maximum annual cost of soil nutrient loss was estimated in the "TRujs" geological formation (1.23×10^6 US\$) consisting of "gray shale, silt, sandstone, conglomerate" and the least cost belonged to the "Jl1" geological formation ($0.916*10^6$ US\$) which consists of "thin gray dolomite limestone". In economic terms there was a direct relationship between soil nutrient loss and its economic cost.

Key words: *Economic valuation, Rainfall simulator, RC method, RUSLE model, Soil erosion*

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1 INTRODUCTION

Water erosion causes a series of on-site as well as off-site damages and problems on natural ecosystem services throughout the world. These damages include soil and nutrient loss (Kuhlman *et al.,* 2010). Loss of soil nutrient and productivity is the main on-site effect of soil erosion, while enhanced productivity of downstream land, sedimentation and eutrophication of waterways and reservoirs are common off-site effects of soil erosion (Telles *et al.,* 2013). Long term productivity loss of degraded soil and a wide range of environmental problems derived from sediment delivery to the drainage network and reservoirs causes cost to society (Gary, 2001; Hansen and Ribaudo, 2008). In this respect, and in order to assess the soil nutrient retention as one of the most important functions of rangelands vegetation, soil erosion rates, sediment associated nutrient and its economic on-site cost are calculated.

Economic costs of the soil erosion are calculated on the basis of on-site effects (losses within the production unit) and off-site effects (damage caused beyond the agricultural properties) (Hansen and Ribaudo, 2008). Few studies have been aimed at knowing the economic implications of erosion, this being the message that farmers and/or policy makers would understand better in order to perceive and recognize the problem and to implement conservation measures, both at the field level and the catchment level. In the United States, the annual cost of soil erosion for both on-site and off-site effects has been estimated at 44 billion dollars a year (Telles *et al.,* 2011). In the European Union, the figure is 38×10^12 Euros a year (Telles *et al.,* 2011).

The economic costs of soil loss will be calculated by market prices of chemical fertilizer and will be considereded as soil conservation value. Economic valuation of any resource can be expressed in terms of direct or indirect economic benefit or loss in money generated by that resource. The valuation of benefit or loss in money is in terms of the amount saved due to increased nutrient status or amount to be incurred for increasing the nutrient status, respectively (Kiran and Kaur, 2011). No single method has been established for valuing soil loss, but rather there are a number of different possible approaches for costing soil erosion (Ghorabni and Hosseini, 2006). Each of these approaches operates from different perspective and has its inherent drawbacks. Some of these methods includes replacement cost, rehabilitation cost, contingent valuation, hedonic pricing, market value of soil, production value of soil and opportunity cost (Pugliesi *et al.,* 2011). Most of valuation studies have been carried out using a single method, such as change in soil fertility. Ghorbani and Hossein (2006) used the replacement cost method (RCM) to estimate the cost of nutrients in the selected sites in Iran. The main reasons for using the RCM in this research can be attributed to appropriateness of the obtained data, usage of the market prices, practical application and generation of almost correct results (Bakhtiari *et al.,* 2009). Hacisalihoglu *et al.* (2010) explained the main specifications of this valuation method and attempted to estimate the cost of soil erosion to society as a whole. The cost of soil erosion is not so much dependent on the physical amounts of soil lost (Drechsel *et al*, 2004). There are many different models to determine the economic value of the soil erosion (Richardson and King, 2007). To date, in most studies of economic assessment of soil degradation, the RCM approach has been used. This approach was called replacement cost method (RCM) and had been used for main nutritional elements such as NPK (Gary *et al.*, 2001; Agheli kohneshari and Sadeghi, 2005; Panahi *et al.*, 2007; Bakhtiari *et al.*, 2009; Pugliesi, *et al.*, 2011).

Although some authors consider that estimates of the specific on-site effects of soil erosion, such as the replacement cost of lost nutrients or damaged infrastructures, give only a very partial vision of the cost of erosion in agricultural fields (Alfsen *et al.*, 1996), they can be useful to show the dimension of specific problems at the field scale in the short-term, without the need for long yield data sets, (Gunatilake and Vieth, 2000). Models have their own perspectives, but also have their own natural limitations (Ghorbani and Hosseini, 2006). In a plethora of similar studies, the negative consequences of nutrient depletion under agriculture activities are recognized widely, but until now few attempts have been made to estimate the magnitude of soil erosion costs in natural ecosystems such as rangelands. In this research, soil erosion and nutrient loss amounts from eroded soils determined in a summer rangelands area in the north of Iran. This paper described the methods used for impact assessment of soil erosion and related forms of soil degradation (loss of soil organic matter) in a watershed dominated by rangelands.

2 MATERIAL AND METHOD

2.1 Description of study area

The study area is a mountainous watershed, called Nour-rud watershed, located in the southwest of the Mazandaran Province, north of Iran. The watershed area is 1299.78 km^2 and lies between 36° 00' 58" to 36°16' 36" N latitudes and 51°18' 21" to 51°26' 13" E longitudes as shown in Figure 1. The elevations of the highest and lowest points are 4333 m and 721 m above mean sea level, respectively (Figure 1). Climatic condition of the area is semi-arid (cold) with mean annual rainfall of about 325.23 mm, and average temperature of 19.7 °C in summer and 3.9 °C in winter. According to land use classification, the most common land use type is rangeland (74%), and other classes include forest (5.01%), rainfed agriculture (0.3%), irrigated agriculture (3.42%), and scrublands (17.26%). The soil texture of the region is loamy, silt-clay-loam and silty-loamy without any development in profile. There are also 12 geologic formations viz. E_K^{gt}, E_K^{sh}, E^{ba},Q^{gd}, $M^{m,s,l}$, $J_{l1,}$ Ktzl from Cenozoic, Paleozoic and Mesozoic eras (Rastgar, 2013).

2.2 Estimation of total soil erosion and sediment yield

Both primary and secondary data was used in this research. Primary data (topographic map, land-use map, soil map and geologic map) were collected from different governmental and non-governmental organizations. In addition to this, frequent field observations using Global Positioning System (GPS) were carried out to generate primary information regarding the ground truth for geologic map. Secondary data were collected using key informant discussions and filed survey or ground truth observations and verification using GPS instruments. Data analysis and processing were made by digitizing, calculating and classifying the necessary information of each thematic layers using ArcGIS 9.3 software.

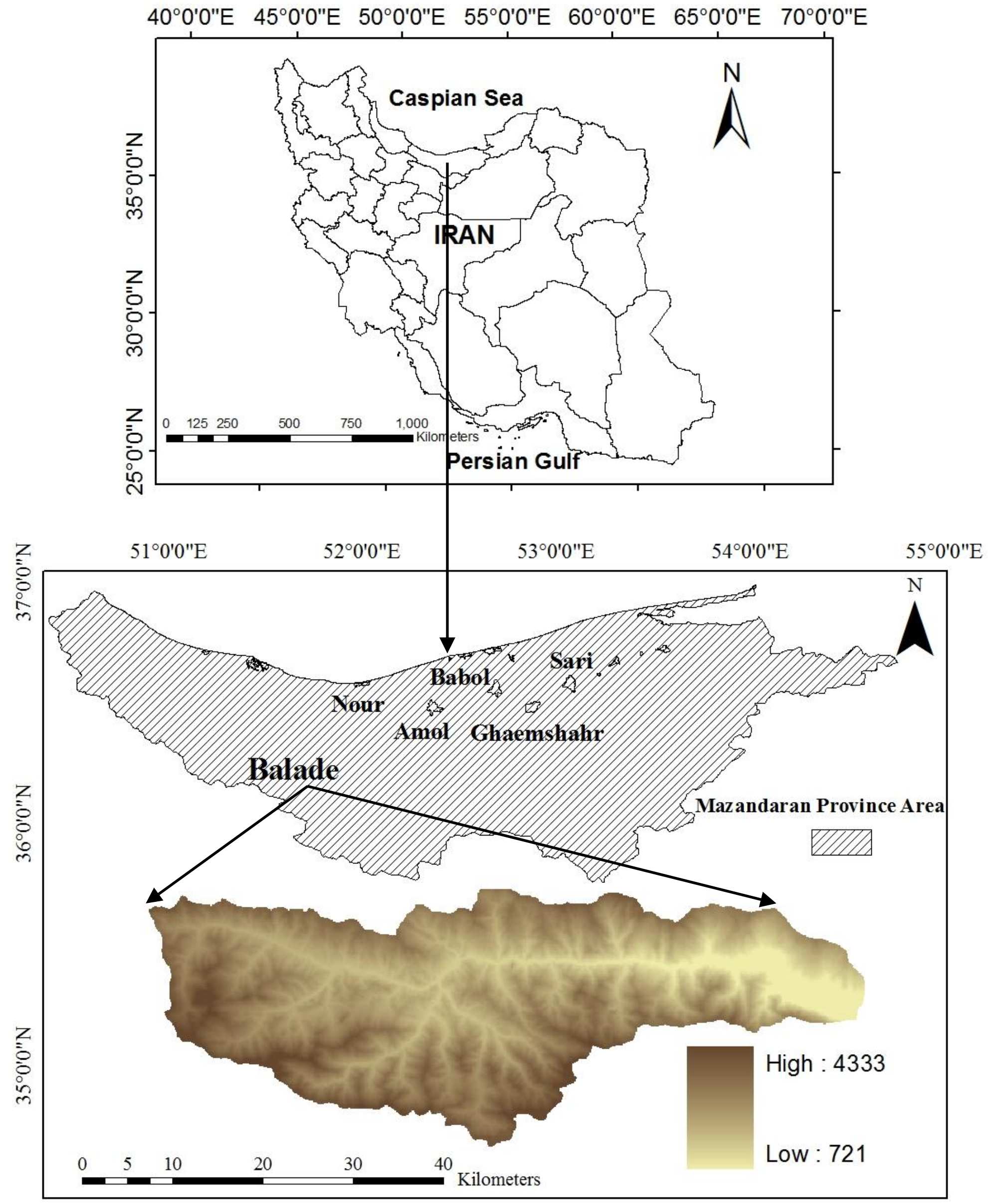

Figure 1 Location of the study area in Mazandaran Province, Iran

There are many models for estimating soil erosion and sediment yield that each of them have used different factors affecting soil erosion. One of them is Revised Universal Soil Loss Equation (RUSLE). This model has distinct advantages when attempting to identify the spatial patterns of soil loss present within a large region. Application of the RUSLE within Nour-rud watershed affords readily available data fairly simple to apply; and compatiblity with GIS (Beskow *et al.,* 2009). In this study, the RUSLE input variables in a GIS environment were used to estimate spatial soil erosion of Nour-rud watershed. The GIS then used to isolate and query these locations to produce vital information about the role of individual variables in contributing to the observed erosion potential value. Sediment delivery ratio was considered as 25% (Yazdani and Abbasi, 2010; Rastgar, 2013). The RUSLE predicts soil loss for a given site as a product of six major factors (Eq.1), whose values at a particular location can be expressed numerically (Amsalu and Mengaw, 2014). The soil erosion was calculated using Eq. (1):

$$A = R.\ K.\ L.\ S.\ C.\ P \qquad (1)$$

Where A is the average soil loss per unit area (t $ha^{-1}\ y^{-1}$), R is the rainfall erosivity factor (MJ mm $ha^{-1}\ h^{-1}\ y^{-1}$), K is the soil erodibility factor (t h $MJ^{-1}\ mm^{-1}\ y^{-1}$), L is the slope length factor, S is the slope steepness factor, C is the plant cover and management practice factor, and P is the conservation support practice factor (Arekhi *et al.*, 2012). The L, S, C, and P values are dimensionless (Amsalu and Mengaw, 2014). The overall methodology involved the use of the RUSLE in a GIS environment, with factors obtained from meteorological stations (Meteorological Organization of Mazandaran Province), soil surveys (Watershed Management bureau of the Ministry of Agricultural Jihad of Iran), topographic maps with scale of 1:50000 (Mapping Organization of Iran). The layer of each factor was built in the Arc GIS to predict soil loss and sediment yield in a spatial domain (Drechsel *et al.*, 2004; Arekhi *et al.*, 2012). The spatial resolution of the data was set to 200 meter.

2.3 Estimation of total soil nutrients loss

Different land use types of rangelands, different slope classes in each type and different geologic formations were chosen to set up a portable rainfall simulator (E65) to complete necessary information namely soil loss nutrients (N, P, K). According to the great influence of geologic formations in soil loss and sediment yield, dominant three types of geologic formations in the rangelands with large extension in the region were selected (Cerda, 1999; Feiznia *et al.*, 2003). Geologic formations of the geology map (scale: 1:100000), belonged to Cenozoic, Paleozoic and Mesozoic era that were spread in different area in the region. Due to these different formations, three sites were selected for rainfall simulation. The sites selected by GPS in dominant geologic formations; namely, "TRujs" with an area of 568.19 km^2, "EKgt" by 299.17 km^2 and "Jl1" by 59.39 km^2 covers the most area of Nour-rud watershed respectively. Petrology composition of "Jl1" was thin grey dolomite limestone, "TRujs" by grey shale, silty, sandstone, conglomerate and "EKgt" by green tuff. For each sites, 9 experimental plots (1*1) m^2 were established. Mean slope of the plots were 35% (Rastgar, 2013). The rainfall simulator structure and components have been shown in Figure 2.

Sampling plots were bounded by a galvanized iron sheet (12 cm height) to reduce the splash effect of the rain drops. After each rainfall simulation, the runoff and sediment were measured in each experimental site by a scaled cylinder (Drechsel *et al.*, 2005). In autumn and winter, runoff and sediment measurements were not done, since most of the sampling areas were covered by snow. Soil loss amounts from the plots and also total nitrogen, usable phosphorus, exchangeable potassium from dried and sieved eroded soils were determined in the research area. Total soil nutrient loss for one year (in 2010) determined using Eq. (2):

$$D_{um} = S \times M_n \qquad (2)$$

Figure 2 Design and structure of the portable rainfall simulator

Where D_{um} is nutrients loss (kg ha^{-1} y^{-1}), S is sediment loss (t ha^{-1} y^{-1}) and M_n is soil element ratio in current year (Hacisalihoglu *et al.*, 2010; Mobarghei, 2010).

2.4 Soil analysis

After simulation and transporting samples to the laboratory, chemical analyses were accordingly done. The residual runoff got dried in oven for 24 hour and in 105°C

(Mobarghei, 2010). The total sediment for each simulation was determined. Total nitrogen (N), was determined with the LECO (Laboratory Instruments for the elemental analysis of Carbon, Hydrogen etc.) nitrogen measurement analyzer by dry weigh method (Hacisalihoglu *et al*., 2010). Phosphorous (P) was determined according to the Bray and Kurtz (PH<7.4) method in the spectrophotometer analyzer (Hacisalihoglu *et al*., 2010). Exchangeable potassium (K) was determined in the flame photometer device according to the one normal ammonic (if Ph>7 with acetic acid) (Hacisalihoglu *et al.*, 2010).

Total soil nutrient loss was ultimately calculated according to Eq. (3):

$$A_n = D_{nN} + D_{nP} + D_{nK} \quad (3)$$

Where A_n is total soil nutrient loss (nitrogen, phosphorous and potassium) (Hacisalihoglu *et al.*, 2010; Mobarghei, 2010).

2.5 Economic valuation method of soil nutrient loss

In this study, economic value was assessed by the amount of fertilizer required for replacing nutrients which are deficient in the soil or the amount that is saved where nutrients are retained in the soil. Thus the amount of NPK, lost from the soil or retained in the soil was estimated, and then was subjected to economic valuing (Mobarghei, 2010). The RCM was used based on reducing soil erosion by productive potential of the soil. This includes depletion of the soil nutrient content, its physical structure and ecological qualities (Ghorbani and Hosseini, 2006). The present study focused on assessment of the economic loss or benefit due to changes in nutrient status of rangelands soil. The decrease or increase in nutrient status; i.e., NPK, affect the fertility status of any area, which is calculated based on the NPK content in the soil (Kuhlman *et al.*, 2010; Yazdani and Abbasi, 2010; Hacisalihoglu, 2010; Telles *et al.*, 2013). Therefore, the analyses estimate the value of reduction in soil productive potential in terms of depletion of the soil nutrient resource base. It is calculated as the market value of the difference between soil nutrient content as an eroding soil and not eroded soil (Telles *et al.*, 2013). The method undervalues the soil from society's perspective. According to the great subsidy of the government for this chemical manures in Iran, real price of the manures were considered (without considering subsidy) (Panahi *et al.*, 2007). For account soil nutrient loss in different replacement manures, urea manure used for nitrogen lack, ammonium phosphate for phosphorus and potassium sulfate for potassium. By considering market price of manures and the Eq. (4), soil nutrient loss value calculated (Pugliesi *et al.*, 2011).

$$V = \sum(P_N D_N + P_p P_p + P_K D_K) \quad (4)$$

Where V is total economic value of soil nutrient loss and P_N, P_P, and P_K respectively, are replacement manure prices for NPK and D_N, D_P, D_K, are (Panahi *et al.*, 2005). The study valuation was based on the market cost of the equivalent fertilizers during the studying year. Figure 3 depicts the entire methodology of economic valuation.

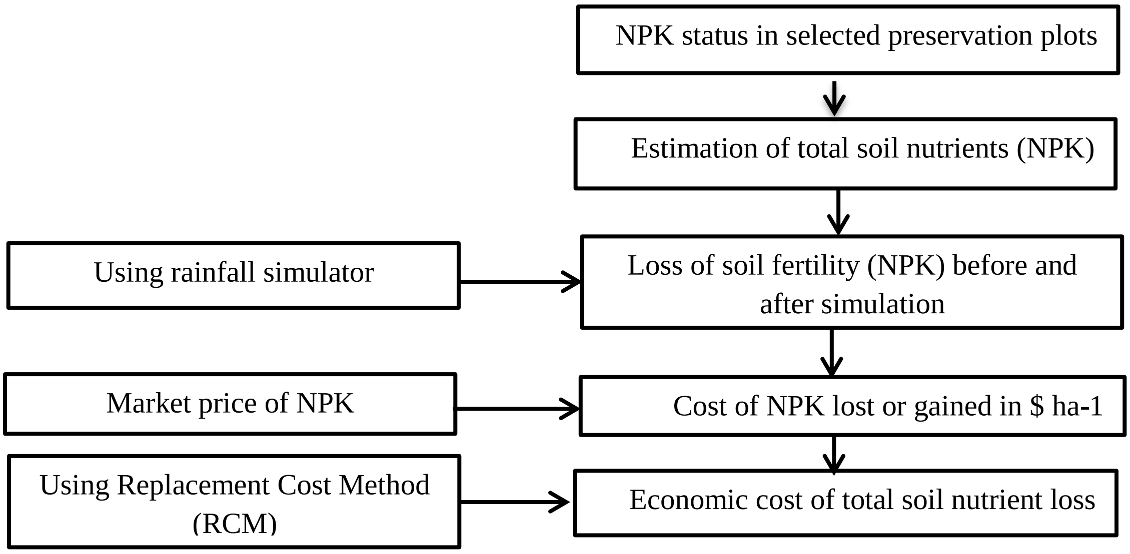

Figure 3 Economic valuation of soil nutrient loss

3 RESULTS

3.1 Annual soil loss and sediment yield

The input parameters of RUSLE model and GIS used to estimate spatial soil erosion and sediment yield of the Nour-rud Watershed, Mazandaran Province, Iran. The values of the R, K, LS, C and P factors have showed in Table 1. Average annual soil loss was estimated by multiplying R, K, LS, C and P factors with use of ArcView software. The mean annual soil loss estimated for the study area using the RUSLE was put at 27.44 t ha^{-1} y^{-1}. The erosion rate in the studied area ranged from 0.0 to 996.06 t ha^{-1} y^{-1} (Figure 4).

Annual sediment yield estimated to 25% of soil erosion that estimated 6.86 t ha^{-1} y^{-1} for rangelands (Yazdani and Abbasi, 2010).

3.2 Annual soil nutrient loss

The average total nitrogen, usable phosphorus, exchangeable potassium from simulated plots in research sites is shown in Table 2. It showed that the ratio of soil nutrient loss of one storm event of simulated rainfall in g m^{-2} converted to t ha^{-1} y^{-1} by the RUSLE erosion model as shown in Table 2. The maximum soil nutrient loss belonged to unit 1, "TRujs" by the average of 267.8 kg ha^{-1} and the minimum was belonged to unit 1"Jl1" by the average of 38.87 kg ha^{-1}. Average soil nutrient loss of NPK in sampling points was 114.17 kg ha^{-1} as shown in Table 2.

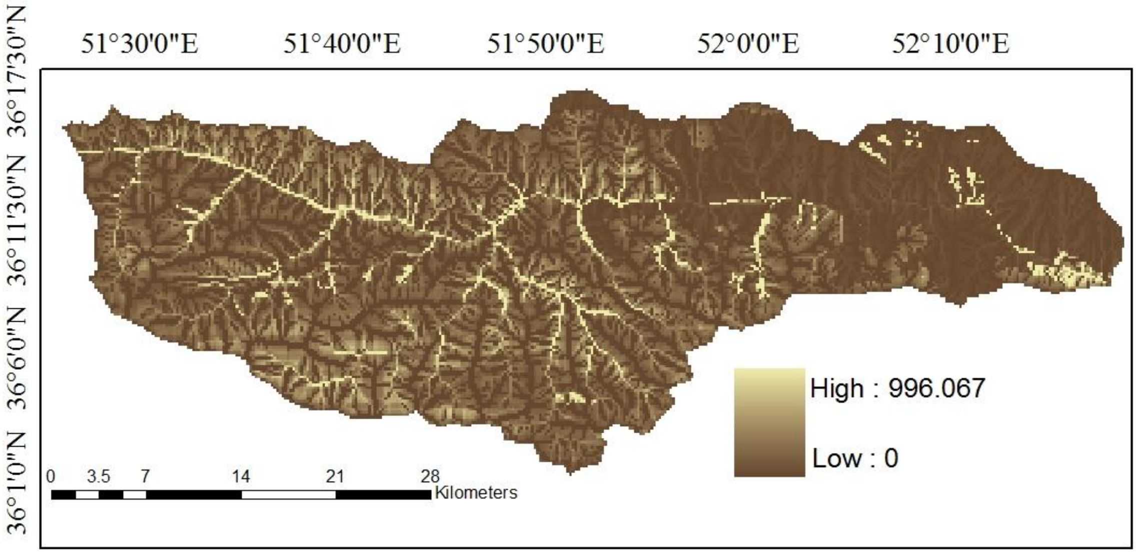

Figure 4 Soil erosion (t ha^{-1} y^{-1}) map of Nour-rud Watershed

Table 1 Annual soil loss and the RUSLE factors for the study area

The RUSLE Factors	Results
R	2647.86 (MJ mm ha^{-1} y^{-1})
K	0.073 (t h MJ^{-1} mm^{-1} y^{-1})
LS	2.30
C	0.06
P	1
Annual soil loss	27.44 (t ha^{-1} y^{-1})

3.3 Economic cost of total soil nutrient loss

Replacement cost method (RCM) used for estimating economic cost of soil nutrient loss. Fertilizer prices were estimated by considering world price of chemical fertilizers (as replacement goods by market price) for restoring soil fertility (without subsidy) (Table 3). Fertilizers were namely; CH_4 N_2O, HPO_4 $(NH_4)_2$ and K_2SO_4 that are not produced or sold at the same cost or price by pure N, P and K nutrients. A pure percentage of N is 0.45 of CH_4 N_2O; pure percentage of P is (0.19*HPO_4 $(NH_4)_2$) and pure percentage of K is 0.50 percentage of K_2SO_4. Results of Table 3 showed that a unit of phosphorus is far more expensive than a unit of K or N. In order to express the cost of fertilizer in nutrient units rather than in product units, some idea of the cost or price ratio between these three macro-nutrients is needed.

According to the results as shown in Table 4, total soil nutrient loss in 94978 ha rangelands was 6.8×10^6 US$. Economic cost of soil nutrient loss estimated 71.5 US$ per ha of Nour-rud rangelands. As shows in table 4, the maximum and the minimum annual soil nutrient loss per ha, were estimated 27.4 US$ and 114.2 US$, which belong to the geologic unit 1 and unit 2, respectively.

Table 2 Soil nutrient loss amount in each sampling points (2010**)**

Sampling points	Area (ha)	Average nutrient loss ($g\ m^{-2}$)			Average sediment weight ($g\ m^{-2}$)	Average nutrient loss ($kg\ ha^{-1}$)
		K	P	N		
Unit 1 (TRujs)	44800	2.24	0.146	1.49	667.7	267.8
Unit 2 (EKgt)	40710	11.24	0.416	4.46	720.2	161.30
Unit 3 (Jl1)	9468	13.81	2.08	10.87	660.2	38.87
Total	94978					
Average		7.25	0.45	5.62		114.17

Table 3 International and subsidized prices for manures

Product (Manures)	$CH_4\ N_2O$		$HPO_4\ (NH_4)_2$		K_2SO_4	
	International	subsidized	International	subsidized	International	subsidized
Percentage of pure Nutrient in manures	0.45	0.45	0.19	0.19	0.50	0.50
Pure Unit ($\$\ g^{-1}$)	0.6	0.04	1.47	0.05	0.72	0.04

Reference: www.fertecon.com and Government subsidies for chemical manures in Iran

Table 4 Economic cost of annual soil nutrient loss (2010)

Sampling points	Soil nutrient loss (US\$ ha^{-1})			Economic cost per ha US\$	Total economic cost US\$[1]
	K	P	N		
Unit 1 (TRujs)	16.2	2.2	9.1	27.4	1227663
Unit 2 (EKgt)	81	6.1	27.1	114.2	4650599
Unit 3 (Jl1)	0.01	30.7	66	96.7	915861
Total					6794123
Average				71.5	

[1] . US Dollar equals to 10330 Rial in 2010 (Central Bank of Iran statistics)

4 DISCUSSION

The spatial distributions of amount of soil loss in the study area was quite different and was varied from nearly insignificant (0.00) in south, west and central parts of the study area to extremely high (504.6 t ha y^{-1}) in the north and northeastern parts of the watershed (Figure 4).

The mean annual soil loss of total area is 27.44 t ha^{-1}, which make a total loss of 2,606,196 ton y^{-1} from 94978 ha of the rangelands (Table 2). Since the east and north-eastern parts of the watershed is dominated by steeply sloping areas, an estimated soil loss in this area is greater than the other parts of the watershed.

In addition the overall result of the study was found in line with the findings of Beskow (2009) and Arekhi *et al.* (2012), who came in to the conclusions that according to the RUSLE model, about 6.86 ton of eroded top soils in ha transported to the outlet of the basin with soil erosion event. This amount of soil erosion and sediment is under the influence of geologic formation, plant vegetation type, land use, land slope and support practice factors of the studied area; that caused to different amount of erosion (Cerda, 1999).

The RUSLE model combined with GIS was effective to estimate the potential of soil erosion for the study watershed. Based on overlaying 5 variables and the raster calculator, the model was accurately depicted. For a more precise calculation the P factor will need to be more exact, since this project assumed P factor as a constant value of 1 over the target area. This amount of soil loss and sediment should help to explain the high economic value of soil erosion and the important role of rangeland geologic physical characteristics in prevention of soil erosion and sediment yield and the big relationship between ecosystem structure and function.

Summer rangelands of Nour-rud watershed act as nutrient source and sink. They contain high amount of nitrogen, phosphorous and potassium as compared to different parts of the region geologic formations. In comparison with the nutrient loss measured in the field due to the rainfall simulator, the proportion of nutrients with respect to the net soil loss, average total nitrogen, usable phosphorus, and exchangeable potassium valued from different geologic formations. The maximum nutrient loss was found in "TRujs" (2470 g m^{-2}). The minimum nutrient loss was found in "Jl1" (3.88 g m^{-2}) which obtained in the measurement plots in the research area. The reason for these differences was their geologic formation under natural vegetation.

Besides that, it is known that there are many different methods to calculate the economic value of soil erosion event. But almost all of them have their restrictions and negative sides, like RCM used in this study. RCM can be applied as an indicator evaluates sustainability of soil management systems. However, in long-term experiments, the annual variation of prices of fertilizers and labor could mask the effects of the treatment themselves (Pugliesi *et al.*, 2011). This kind of approach does not measure the damage to other environmental goods and services, such as neither the loss of biodiversity, nor other impacts resulting from the erosion process that affect other parts of the ecosystem (Kuhlman *et al.*, 2010). Different studies ascertain that economic calculations grossly underestimate the current and future value of natural capital (Drechsel *et al.*, 2009). The main reasons for using the method is determining the economic value of soil erosion that can be collected as; appropriateness of the obtained data, usage of the market prices, practical application and almost correct results generation. In similar studies the negative consequences of nutrient depletion under agriculture are recognized widely, but until recently few attempts have been made to estimate the magnitude of the costs involved in natural ecosystems such as rangelands. It is therefore necessary to take in to account that this method attempts to estimate the cost of soil erosion to society as a whole. The fertilizer prices changes persistently in the market and therefore, calculated prices with this method evaluate the land values high.

5 CONCLUSION

Analyzing economic valuation for any resource is subtle as it requires large, multi-temporal data, which are difficult to acquire. In addition, it requires a localized approach. However, as a means of quantitatively measuring and assessing the cost and benefit of the different rangeland conservation activities, economic valuation is necessary. It is an essential factor for achieving greater management sustainability and efficient management.

6 REFERENCES

Adhikari, B. and Nadella, K. Ecological economics of soil erosion: a review of the current state of knowledge. Ann. Ny. Acad. Sci., 2011; 1219: 134-152.

Agheli Kohneshahri, L. and Sadeghi, H. Economic valuation of soil erosion in IRAN. Econ. Res., 2005; 15: 87-100. (In Persian)

Alfsen, K.H. Franko, M.A.D. Glomsrod, S. and Johnsen, T. The cost of soil erosion in Nicaragua. Ecol. Econ., 1996; 16(2): 129-145.

Amsalu, T. and Mengaw, A. GIS based soil loss estimation using rusle model: the case of jabi tehinan woreda, ANRS, Ethiopia. Nat. Resour., 2014; 5: 616-626.

Arekhi, S., Darvishi, A., Shabani, A., Fathizad, H., and Ahmadai Abchin, S. Mapping soil erosion and sediment yield susceptibility using RUSLE, remote sensing and GIS (Case study: Cham Gardalan Watershed, Iran). J. Adv. Environ. Biol., 2012; 6(1): 109-124. (In Persian)

Bakhtiari, F; Panahi, M; Karami, M; Ghoddusi, J; Mashayekhi, Z and Pourzadi, M. Economic valuation of soil nutrients retention function of Sabzkouh forests. Iran. J. Forest. 2009; 1(1): 69-81. (In Persian)

Beskow S., Mello, C. R., Norton, L. D. Curi, N., Viola, M.R., and Avanzi, J.C. Soil erosion prediction in the Grande River Basin, Brazil using distributed modeling. Catena, 2009; 79: 49-59.

Cerda, A. Parent material and vegetation affect soil erosion in eastern Spain. J. Soil Sci. Soc. Am., 1999; 63(2): 362-368.

Drechsel, P., Giordano, M., and Gyiele, L. Valuing nutrients in soil and water: concepts and techniques with examples from IWMI studies in the developing world. Research report 82. Colombo, Srilanka: Int. Water Manag. Ins., 2004; 280 P.

Feiznia, S., Sharifi, F. and Zare, M. Sensibility of formations to erosion in Chandab watershed basin of Varamin. Pajouhesh-Va-Sazandegi J. 2003; 61: 33-38. (In Persian)

Gary, R., Gunatilake, H. and Cox, L.J. Economics of soil conservation: The upper Mahaweli watershed of Sir Lanka. J. Agr. Econ., 2001; 52(1): 139-152.

Ghorbani, M. and Hosseini, S. The application of replacement cost approach in estimating the annual cost of water soil erosion in IRAN. J. Agr. Res., 2006; 7(3): 177- 186. (In Persian)

Gunatilake, H.M. and Vieth. G.R. Estimation of on-site cost of soil erosion: A comparison of replacement and productivity change methods. J. Soil Water Conserv., 2000, 55(2): 197-204.

Hacisalihoglu, S., Toksoy, D. and Kalca, A. Economic valuation of soil erosion in a semiarid area in Turkey. Afr. J. Agric. Res., 2010; 5(1): 1-6.

Hansen, L. and Ribaudo, M. Economic Measures of Soil Conservation Benefits: regional values for policy assessment. TB-1922. U.S. Dept. of Agriculture, Econ. Res. Serv. 2008. Accessible at: www.errs.usda.gov.

Kuhlman, T., Reinhard, S. and Gaaff, A. Estimating the costs and benefits of soil conservation in Europe. Land Use Policy. 2010; 27: 22-32.

Mobarghei, N. Estimating the economic value of soil nutrient retention in forest ecosystems. Environ. Res. J., 2010; 4(7): 3-12. (In Persian)

Panahi, M., Saiid, A., Koopahi, M., Makhdoom, M. and Zahedi, Gh. How much is the monetary value of soil protection function of Caspian forests? A survey on three forest areas in the north of Iran. 2007.76: 2-10. (In Persian)

Pugliesi, A.C.V. and Marinho, M.A. Marques, J.F.; Lucarelli, J.R.F. Economical valuation of the erosion effect in soil management systems employing the replacement cost method. Bragantia. 2011; 70: 113-121.

Rastgar, Sh. Estimating and Comprising the Economic Value of Forage Production and Soil Conservation Functions of Range Vegetation (Case study: Noor-rud Watershed basin, Mazandaran Province). PhD thesis. Gorgan University of Agr. Sci. Nat. Res. 2013; 158 P. (In Persian)

Sandhya Kiran, G. and Malhi Ramandeep Kaur, M. Economic valuation of forest soils. Current Sci. J., 2011; 100 (3): 396-399.

Telles, T.S. and Carmela Falci Dechen, S., Souza, Gustavo Antonio de Souza, L., Guimarães, M.D.F. Valuation and assessment of soil erosion costs. Sci. Agric., 2013; 70(3): 209-216.

Telles, T.S., Guimarães, M.F. and Dechen, S.C.F. The costs of soil erosion. Revista Brasileira de Ciência do Solo. 2011; 35(3): 287-298.

Yazdani, S. and Abbasi, A. Economic valuation of forest environmental benefits. (Case study: Kheirud forest in Noshahr). J. Agr. Econ. Res., 2010; 5(1): 33-54. (In Persian)

برآورد هزینه اقتصادی ناشی از هدررفت عناصر مغذی خاک در مراتع ییلاقی حوزه آبخیز نوررود– شمال ایران

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چکیده فرسایش آبی خاک آثار مخرب مستقیم و غیرمستقیمی بر زیست‌بوم‌های طبیعی به همراه دارد. این آثار مخرب موجب فرسایش خاک، هدررفت عناصر مغذی خاک و در نهایت کاهش حاصلخیزی خاک می‌شود که همراه با تحمیل هزینه‌هایی به جامعه خواهد بود. لذا، تحقیق حاضر با هدف تعیین ارزش اقتصادی کارکرد حفظ حاصلخیزی خاک به‌عنوان یکی از مهم‌ترین کارکردها و خدمات پوشش گیاهان مرتعی و هزینه اقتصادی ناشی از کاهش حاصلخیزی آن به انجام شد. مقادیر هدررفت خاک با استفاده از مدل RUSLE و سیستم اطلاعات جغرافیایی (GIS)، در مناطق با میزان حساسیت مختلف به فرسایش به‌دست آمد. اطلاعات تکمیلی مورد نیاز مانند مواد غذایی مهم خاک اعم از نیتروژن، فسفر و پتاسیم با استفاده از پلات‌های قابل حمل دستگاه باران‌ساز مصنوعی مدل (E65) به‌دست آمد. شبیه‌سازی باران و تعیین میزان هدررفت عناصر مغذی خاک در سه سایت و در نه پلات ۱*۱ متر بر اساس نقشه زمین‌شناسی و میزان حساسیت خاک به فرسایش انجام شد. با در نظر گرفتن این‌که هدررفت عناصر مغذی خاک طی فرسایش می‌تواند با کودهای شیمیایی جبران شود، هزینه اقتصادی عناصر مهم غذایی با استفاده از قیمت بازاری کودهای شیمیایی برآورد شد. نتایج نشان داد که میانگین فرسایش خاک با استفاده از RUSLE، ۲۷/۴۴ تن در هکتار در سال بوده است. هم‌چنین به‌طور میانگین هر هکتار از اراضی مرتعی مورد مطالعه در سال پایه تحقیق، ۱۱۴/۱۷ کیلوگرم از عناصر (NPK)، به ارزش ۷۳۸۹۴۴ ریال (۷۱/۵ دلار) را در اثر فرسایش خاک از دست داده است. هزینه کل هدررفت عناصر مغذی خاک در ۹۴۹۷۸/۶ هکتار اراضی مرتعی حوزه آبخیز نوررود، معادل ۷۰ میلیارد ریال (۶/۸ میلیون دلار) برآورد شده است. بیش‌ترین میزان هدررفت و هزینه اقتصادی سالانه عناصر مغذی خاک (۱/۲۳ میلیون دلار) متعلق به سازند زمین‌شناسی شمشک "TRujs" با ترکیب سنگ‌شناختی "شیل خاکستری با ترکیبات سیلت، ماسه سنگ و کنگلومرا" و کم‌ترین مقدار نیز متعلق به سازند لار "Jl1" با ترکیب "سنگ آهک دولومیتی، نازک لایه خاکستری روشن" (۰/۹۱۶ میلیون دلار) بوده است. در تحقیق حاضر، رابطه مستقیمی بین میزان هدررفت عناصر مغذی خاک و هزینه اقتصادی ناشی از آن وجود داشته است.

کلمات کلیدی: ارزش‌گذاری اقتصادی، باران‌ساز مصنوعی، روش هزینه جایگزین، فرسایش خاک، مدل RUSLE