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Investigation of Afforestation Area on the Amount of Sediment Production in Natural Forests

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ABSTRACT
Firstly, physical factors of the area were analyzed. Then, forestation as well was determined for the years between 1993 and 2010. The present study aims to determine the role of forest executive/operations management in the amount of sediment production, as well as to determine a factor to reduce it. Results of the study show that afforestation has the highest effect on sediment production (R^2=0.34) at a confidence level of 95% in the region.
***Keywords**: forestation, sediment, forest road construction, harvesting*

INTRODUCTION

It is well known that precipitations in different regions have changed in different ways under changing climate. Hulme [1] and New et al. [2] constructed a dataset of 100 year-precipitation distributions over the global in the twentieth century, which covers the largest temporal-spatial measured-precipitation data. Based on the trend of global warming, researchers [3,4] figured out that global mean precipitation would increase, accompanied with more extreme precipitation events and increased precipitation intensity. The importance of rainfall pattern such as peak intensity was also emphasized. Precipitation and runoff are direct driving forces of soil erosion and sediment transport. Variation of precipitation will surely lead to the changes of surface runoff, soil erosion and sediment dynamics. Basins as a source for forest and agricultural products in Guilan province are the most convenient and economical local livelihoods environment for human activity. Thus, it is necessary to preserve them: Northern forests of Iran are among the most unique forests in the world. The reduction of erosion and of sediment production in order to preserve the forest soil and to increase forest products have been discussed for so long [5]. Increase in the sediment production and erosion of a basin causes a decrease in the amount of forest products which, in turn, causes hindrance to forestry plans and higher expense in production [6]. Human activity in the basins is one of the factors which cause an increase in the sediment production. Forestry plans are among such activities which are executed by the Forest and Rangeland Organization in the forest basins of Northern provinces. The effect of these activities on sediment production has always been an issue for discussion. Similar research conducted in relation to this issue is briefly reviewed below: Results of a research carried out by Pringle & Bensted [7] showed that executive activities in forests, like harvesting, decreases the flora, and the decrease of canopy cover causes the increase of water erosion and sediment production, so that the amount of sediment carried by surface currents increased from 100 kg per acre to 277 in the first year and to 397 kg per acre in the second year. This study proposes has effect the effect of performed operations management such as road construction and harvesting and afforestion on the amount of sediment production in forest.

MATERIALS AND METHOD

Study Area

The area under study is of 13,284 acres and of a height range between 50 and 1900 meters, located in the Khardjegil basin of Asalem (Nav Asalem) and in Asalem city, Guilan province, in the northern part of Iran . The river Nav runs from the west to the east of the region, flowing into the Caspian Sea. The area under study includes 7 series: namely Daryabon, series 7, 8, and 9; Gile Sararood, series 1; Navrood, series 1 and 2; and Siahbil, series 1, all of which feature forestry plans in the

province. Khardjegil's Sediment Station is located in the basin output, at the height of 130 meters above sea level, and between 48° longitude and 37° latitude.
The soil of the region under study is often of a forest brown, undeveloped type of soil. Soil texture in most of the region is C-L. Up to the height of 1,200 meters, the soil of the area is of an udic moisture regime, and higher than that, the soil is of a xeric regime. Thermal regime of the soil in the region is of a Mazik regime.
The present study analyzed the physical factors of the region under study like Slope, Geographical directions, Height range above sea level, and Geology and Canopy density in percentages. Performed operations management in the region, the amount of road construction, forestation, and harvested volume, as well as the harvesting method in the region, were determined for the years between 1993 and 2010. Reports of Asalem Sediment Station on the basin's sediment production between the years 1993 and 2010 were used. The basin's sediment production was analyzed using the SPSS software and the extacted graphs, in relation to the amount of road construction, the staus of forestation and harvesting.
The basin's sediment production: In order to determine the amount of sediment production in the region, data were used from Asalem's Sediment Station (Khardjegil's) which is located at the height of 130 meters above sea level and registers the amounts of sediment production since 1960. The present study used the data relating to the years between 1993 and 2010. On days when rivers are polluted, sediment samples are taken using the depth method, regarding the level of turbidity. After filtration of the sediment samples, the density of each sample is determined in laboratory. The equation below calculates the instantaneous amount of suspension load in tons per kilometers. Table 6 represents the annual amount of sediment production.
$QS = QW \times CM \times 0.0864$
QS: the amount of sediment
QW: instantaneous value of discharge
CM: average thickness of extracted sediment

RESULTS

Climatic analysis of the region under study using Asalem Weather Station shows that the relative moisture is between 71% and 96%, the average temperature of the region is 24.8 degrees centigrade, and its average evaporation is 745.3 millimeters. Also, the number of frost days in the region is 24 days every year. Low parts of the region feature humid climate, while higher parts of the region feature mid-humid to cold, mountain climate. The average amount of rainfall during the study period was 1186.6 millimeters. The increase of waste and flowing water stream on the surface soil causes an increase in the amount of erosion and sediment production [5]. The average amounts of annual rainfall per millimeters every year, based on data from Asalem Weather Station, are set out in Table 1.

Table 1 - Average amounts of annual rainfall per millimeters every year .

Year	annual rainfall (per millimeters every year)	Year	annual rainfall (per millimeters every year
1993	1191	2002	1267.7
1994	1249	2003	1249
1995	1205.1	2004	968.8
1996	1127.6	2005	1322.5
1997	1122.3	2006	1223.8
1998	1295.3	2007	1217.4
1999	1253.6	2008	1217
2000	1385	2009	1267.3
2001	1078.9	2010	1281

Gradient map and geographical directions, provided by the ARCGIS software v 9.2, show that 51.37% of the region's surface is on a slope class of more than 60%. Three slope classes identified the region under study. Utilization and road-construction management are performed with ease in the first slope class; in the second slope class, utilization and road-construction management are performed with higher expenses and based on engineering principles; the third slope class is a preserved area, and no road construction is performed there. Table 2 presents the slope class categories and areas in the region under study, and table 3 presents geographical directions' status. Table 4 presents the amount of forest canopy density in percentages (the ratio of canopy to ground level). The forest canopy density percentage of each series is provided using information from the forestry plans book. Types presents in the beech area - Hornbeam, Diospyros lotus, hornbeam, oak – include Diospyros lotus and alder. The average amount of dead covering on the forest floor is between 40% and 60%, featuring an endogenous, uneven-aged structure of two or three stories. Forest surfaces present in the area cover 10,360.9 acres; forest open or dilapidated surfaces cover 1,665.17 acres, and preserved surfaces cover 1,311.9 acres. Forest stands near Khardjegil village, activities by forest households, and the presence of livestock in the area cause the quantitative and qualitative status of these stands to be unfavorable.

Table 2 - the slope class categories and areas in the region

Slope Class	Slope category (percentages)	Area (acres)	Area (percentages)
I	0-30	2,653.7	19.97
II	30-60	3,804	28.66
II	>60	6,826.3	51.37

Table 3 – Geographical directions' status

Main directions	Area (acres)	Area (percentages)
North	4,782.24	36
Southeast	5,579.28	42
West	876.74	6.6
Southwest	265.68	2
East	398.52	3
Flat	664.2	5
South	212.54	1.6
Northeast	132.84	1
Northwest	371.95	2.8

Table 4 – The amount of canopy density in percentages

Series	Siahbil, series 1	Daryabon, series 7, 8 & 9	Nav, series 1 and 2	GileSara, series 1
Canopy density (%)	60-70	50-85	55-85	55-65

The present study analyzed the physical factors of the region under study like Slope (Table 2), Geographical directions (Table 3), Height range above sea level, Geology and Canopy density in percentages (Table 4). Performed operations management in the region, the amount of road construction, forestation, and harvested volume, as well as the harvesting method in the region, were determined for the years between 1993 and 2010. Reports of Asalem Sediment Station on the basin's sediment production between the years 1993 and 2010 were used. The basin's sediment production was analyzed using the SPSS software and the extacted graphs, in relation to the amount of road construction, the staus of forestation and harvesting.

Operations Management Performed in the Region

Forestry operations management methods performed in the region between the years 1993 to 2010 are described below:

Forestry plans started in Daryabon, series 7, 8, & 9 since 2005, and single-tree selection mode was performed there. In Siahbil, series 1, clear cutting – ribbon cutting method was performed between the years 1993 and 2000, and after 2005, it switched to single-tree selection mode. Between 1993 and 1995, Nav, series 1 and 2, were parts of the water zone and Cartie Blue method was applied there, and after 2005, it switched to single-tree selection mode. Between 1993 and 2005, Shelter wood method was performed in Gile Sararood, series 1, and after 2006, it switched to single-tree selection mode, and after 2006, it switched to single-tree selection mode. Data relating to the amount of road construction, forestation, and harvested volume, along with the methods performed in the region between the years 2006 and 2010, were extracted from the forestry plans book of the province's Natural Resources Organization, so that the effects of such factors on sediment production could be analyzed and compared. Table 5 presents the harvested volume per square meters, forestation per acres, and forest road construction in kilometers per year.

Regarding the gradient map and the geographical slope directions pattern, results of the study show that the region is located at a relatively high slope class, which causes the increase of water stream velocity. Results of the region's physiography show that more than half of the region is located at a high slope class (table 2). Also, 36% of the area runs northward which, regarding the physiographical mountain climate of the region (being at a height range of 50 to 1,900 m above sea level), affects the sediment production of the area under study: A high slope and a mountain climate, along with a high annual amount of rainfall in the region, cause an increase in water stream velocity and erosion, and an increase in the sediment production of the region in turn. The amount of changes in forestation surfaces, harvesting volume and road construction was analyzed in relation to the sediment production measured at Asalem Sediment Station; the results follow:

Increase in road construction, caused the increase of sediment production. During the years when forest road construction stopped (2005-2008), sediment production decreased (Figure 2-a). Also, the correlation coefficient (R^2) between road construction and sediment production equals 0.54. Results of the ANOVA table suggest that, at a confidence level of 95%, third degree (cubic) regression curve is proper for fitted regression model (Table 4 & Figure 1-b). Figure 2-A shows the sediment production changes in tons per square kilometers, and shows the annual road construction in kilometers. Referring to information registered in the revision plan of the region, trees planted between the years 1998 and 2000 withered away later on because of incorrect methods and a lack of care. In addition, in some of the forestation areas, tree planting was performed with a one-year delay. Therefore, it did not have any positive influence in reducing the sediment production. The correlation coefficient (R^2) between forestation and sediment production equals 0.34. Results of the ANOVA table suggest that, at a confidence level of 95%, linear regression is proper for fitted regression model (Table 7 & Figure 1-A). Figure 2-C shows the sediment production changes in tons per square kilometers, and shows the annual forestation surfaces in acres.

Increase in the transportation of wood and the passing of forest vehicles and tractors over the area while harvesting causes a higher bulk density; and therefore, it stops water absorption and increases surface water streams [8, 9]. Increase of the surface water streams causes sediment production [10]. The volume of harvested wood and the method of harvesting also affect sediment production. Clear cutting method for harvesting wood caused an increase of sediment production during the following years (Figure 2). The correlation coefficient (R^2) between harvested wood volume and sediment production equals 0.50. Results of the ANOVA table suggest that, at a confidence level of 95%, non-linear regression is proper for fitted regression model (Table 8 & Figure 1-C).

Table 5 - The amount of forestation, harvesting, and road construction in the region

Year of the Operations Management	Forestation (acres)	Road Construction (km)	Harvested Wood Volume (square meters)
1993	83	13.22	34,200
1994	78	15.21	34,200
1995	70	17.64	34,200
1996	75	19.61	34,200
1997	79	8.3	34,200
1998	75	5	34,200
1999	92	6.6	38,600
2000	99	3.5	37,500
2001	90	5.5	41,500
2002	103	5.8	46,200
2003	112	6	49,388
2004	79	0	8,800
2005	67	0	9,100
2006	72	0	10,500
2007	70	0	12,500
2008	210	17.18	13,400
2009	160	21.45	14,200
2010	128	22.44	15,700

Table 6 – The annual sediment estimate in tons per kilometers from 1993 to 2010.

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
Sediment Production	46.2	48.6	51.3	65.2	49.2	55.6	97.8	88.7	95.4
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sediment Production	103.8	110.9	70.1	76.1	77.4	80.2	93.2	112.9	125

Table 7 – Variance analysis – forestation

Model	Freedom level	Sum of squares	Mean squares	F value	Level of significance
Regression	1	3,495.668	3,465.668	8.263	0.011
Remainder	16	6,768.863	423.054		
Total	17	10,264.531			

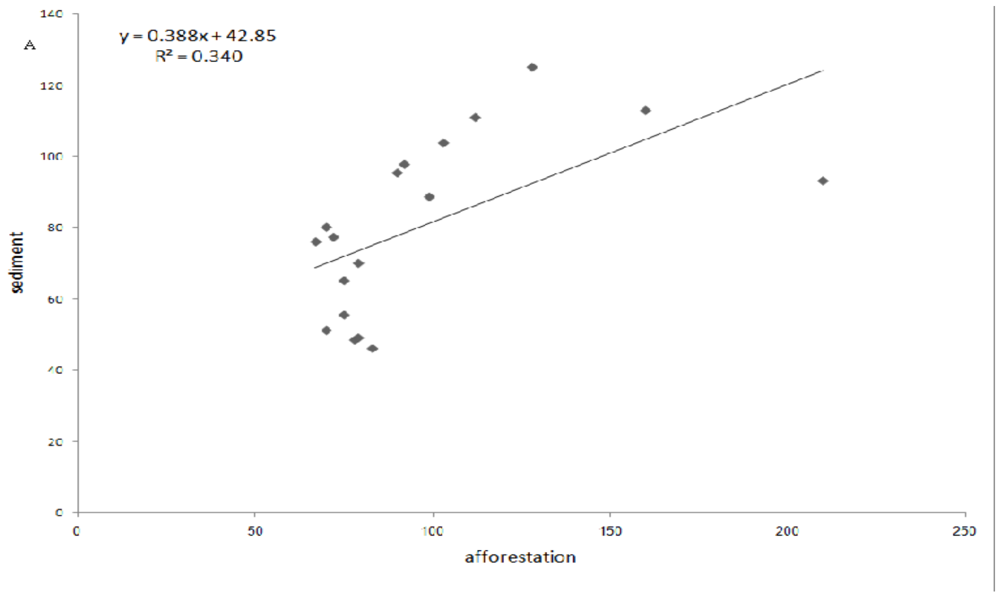

Figure 1. Regression between sediment production and forestation (A)

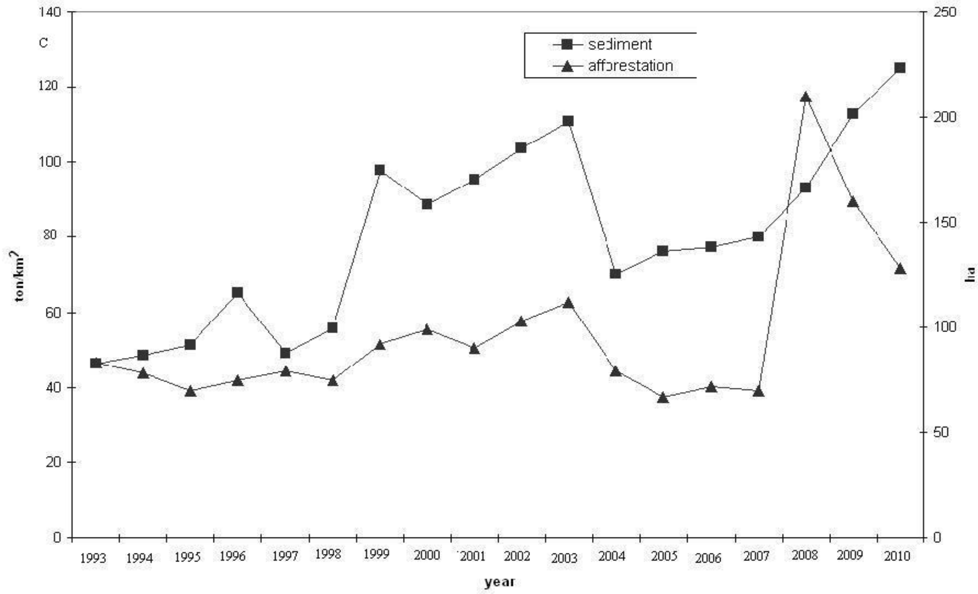

Figure 2. Annual sediment production and forestation curve (C)

According to Table 5-a, the annual sediment production and road construction curve, forest road construction was suspended from 2005 to 2008, and the amount of sediment production reached its minimum during the time period extending from 1993 to 2010. Figure 2-A shows that the amount of sediment production increased because of an increase in forest road construction from 2008 to 2010. The sediment production curve follows an increasing pattern in a time period of 18 years, with a positive correlation coefficient (R^2) of 0.56. The average annual amount of increase equals 3.45 tons per square kilometers. Results of the ANOVA table suggest that, at a confidence level of 95%, linear regression is proper for fitted regression model (Table 10 & Figure 3).

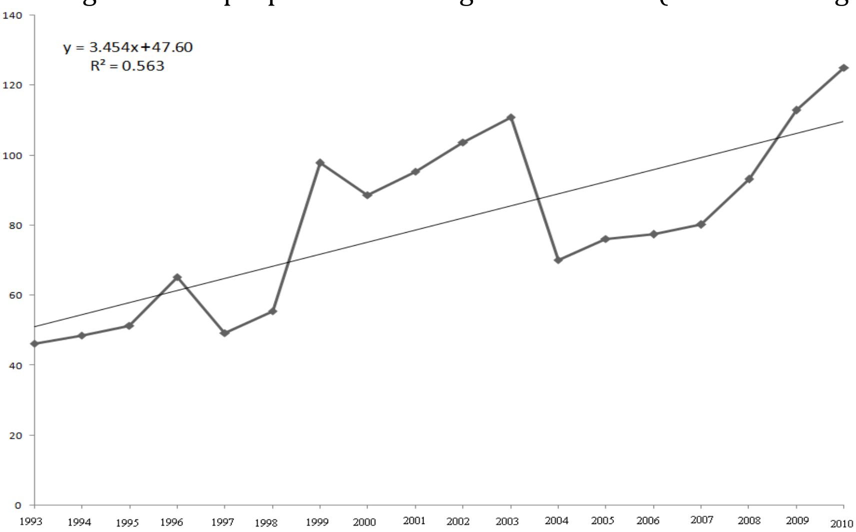

Figure 3 - Sediment production curve in the region from 1993 to 2010 in tons per square kilometers

Table 10 – Variance analysis – the amount of sediment production

Model	Freedom level	Sum of squares	Mean squares	F value	Level of significance
Regression	1	5,782.489	5,782.469	20.264	0.000
Remainder	16	4,482.062	280.129		
Total	17	10,264.531			

DISCUSSION

Results of the study suggest a correlation of 0.54 between the amounts of sediment production changes and the amount of road construction. This occurs as a result of cutting the trees on a road construction route, which lays bare some parts of the forest surface. Intense soil scraping, excavation, and embankment while constructing roads in the region cause an increase in sediment production in the period. A high slope class of the fields causes an increase in water erosion and surface water streams [11]. The region is identified with a slope of 51% which puts it under a high slope class category. A humid, mountain climate and a high amount of rainfall in the region cause an increase in water erosion, and an increase in the sediment production of the region under study. Operations management and management methods used in forest areas affect the amount of sediment production. Forestry management using a clear cutting method and extensive harvesting in the region caused an increase in the amount of sediment production, with a positive correlation coefficient equal to 0.71. So are suggested forestry methods which are in harmony with nature. Research carried out on changes in land utilization and their effect on the amount of sediment and erosion in Belgium showed that even minimal changes in the expanse of forest lands, as a result of their undergone changes, have a significant effect on the amount of sediment production and soil erosion [12]. Stocks of dense forest with a canopy cover of more than 50% (Table 4) play an important role in decreasing surface water streams and protecting the region's soil from direct encounter with storm and heavy rain. Also, the existence of forest stocks with a favorable canopy cover results in the decrease of water erosion and of sediment production [Yu et al., 2006). An increase in the harvesting volume and the decrease of forest surface, especially in classical forestry management methods like clear cutting method, result in the extensive loss of forest canopy cover and, in turn, the increase of sediment production. Zhou in his analysis of land utilization changes and their effect on the amount of sediment production and soil erosion, points out that the decrease of forest surface causes the increase of sediment production and erosion. Since from among forests, dry lands, and pastures, forest lands feature the least amount of sediment production [13, 14], appropriate forestation methods, and forestry management methods friendly to nature become necessary to protect forest canopy.

REFERENCES

1. Hulme, M., (1995). Estimating global changes in precipitation. Weather, 50(2): 34-42.
2. New, M., Hulme, M., and Jones, P., (2000). Representing twentieth-century space–time climate variability. Part II: development of 1901–96 monthly grids of terrestrial surface climate. Journal of Climate, 13: 2217-2238.
3. Allen, M.R. and Ingram, W.J., (2002). Constraints on future changes in climate and the hydrologic cycle. Nature, 419: 224-232
4. Kharin, V.V., Zwiers, F.W., Zhang, X., and Hegerl G.C., (2007). Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. Journal of Climate, 20: 1419-1444.
5. Xinxiao Yu, Xuexia Zhang, Jianlao Li, Manliang Zhang, Yuanyuan Xie. (2006). Effects of vegetation cover and precipitation on the process of sediment produced by erosion in a small watershed of loess region *Acta Ecologica Sinica*, *26(1) :1-8.*
6. Yu X X &Qin Y S. (2001). Effect of forest cover on sediment yield produced by erosion in different spatial scales. *Research of Soil and Water Conservation*, 8(4): 66.69 pp.
7. Pringle, cattherin. M and Bensted, janathan. P. (2001).The effect of logging on Tropical River ecosystem. www.Earth scape.org.
8. Mace, A.C. (1970), Soil compaction due tree length and full tree skidding with rubber skidders. Sci.Jour. Ser. papers no 126.Univ. of. Minnesota
9. Burger, J. A. (1985). Impact of tracked and rubber - tired tractors on a forest soil. Transaction of the ASAE 28 (2): 69-73pp.
10. Cornish, P. M. (1993).Effect of harvesting on run off. Forestry commission of New South Wales. P. o. box 100.79-84pp.
11. An, W.Z., Zhu, L.M., Zhou, W.Q., and Gao, L.L. (2006). Analysis on characteristics and change patterns of precipitation in northwest China. *Agricultural Research in the Arid Areas*, 24(4): 194-199
12. VanRampaey, A. J, G.Govers and C.Puttemans. (2002). Modeling land use change and their impact on soil erosion and sediment supply to rivers, Earth *surface Processes and Land forms*, 24: 481-494 pp.
13. Selby, M.J. (1994). Hill slope sediment transport and deposition. Sediment transport depositional processes, Blackwell, 61-87 pp.
14. Zhou P., O. Luukkanen, T. Tokola, J. Nieminen.(2008). Effect of vegetation cover on soil erosion in a mountainous watershed . *Cantena*, *75* (3): *319-325.*