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Estimate Erosion in Ladiz Dam in Sistan and Baluchistan with Use of Trace Minerals—South East Iran

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Abstract

A survey uses this new information: the statistical calculation and interpretation to determine the characteristics of sediments in the reservoir's "Dodar Ladiz" dam. It is a useful and efficient way to use clay minerals as mineral tracer for identifying the sources and assessing erosion rate in the Dodar Ladiz dam watershed in a statistical method. The existence of four main clay minerals includes Kaolinite, Montmorillonite, Illite and Chlorite. The estimated watershed erosion rate is 2220.64 tons per square kilometer per year. Data ANOVA table in the inter/intra group communication of the clay minerals in the Dodar Ladiz dam watershed samples is shown by F-test statistics; there is a significant difference between the frequency of clay minerals in the samples with 95% confidence rate (P value < 0.05). Therefore, they can be divided into six groups. The average rates of the clay minerals are not equal in any of homogeneous hydrological reservoir units of the dam. Kruskal-Wallis test shows that the rate of frequency of Iolite mineral is identical among all samples of the hydrologic units and the dam reservoir; this mineral cannot be used as a tracer to identify the source. Reviewing the obtained data from statistical tests and studying clay minerals as a trace in determining the rate of degradation of upstream catchment "Dodar Ladiz" dam, it shows that the maximum annual erosion rate is 994.85 tons per sq/km, in the basin A within a 105.13 square kilometers area. Among the most important factors involving erosion and production of basin sediments, we can refer to lithology as the most critical factor and tectonic features, topography and climate as minor factors.

Keywords

Erosion, Statistic Analysis, Trace Mineral, Clay Mineral, Watershed, Ladiz Dam, Sistan and Baluchistan, South East Iran

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1. Introduction

The studied area in this research covers the upstream watershed area of Dodar Ladiz dam in southern part of Zahedan as well as northeast of Taftan volcanic area in eastern part of Iran (**Figure 1**).

This area is located in flysch structural zone of eastern parts of Iran along with Taftan volcanic rocks and Quaternary alluviums (**Table 1**). Hydrologic units were selected as the working congenial units in studying the erosion and determining sedimentation rate (**Figure 2**).

Soil is considered as the most important, expensive and economic environment for plant production. During recent decades, the rate of soil erosion has increased significantly in Iran. Annual rate of soil erosion in Iran has been reported as 33 tons/ha that is 6.5 times higher than the standard limit [1]. Erosion has undesirable economic, social, institutional and environmental consequences in productivity, income distribution and environment and it may play a remarkable negative role in the national and international economy and sustainable and balanced development. Randhir and Hawes (2009) have introduced watershed management and rivers as a basic need in the developing countries and have recommended a continuous monitoring of water quality and quantity as a main task in the watershed domain [2].

In the twentieth century, especially in recent years, several comprehensive studies have been conducted about recognition of erosion factors, the calculation, classification and severity of erosion in the watersheds and the major rivers of the world. The results are mostly based on physical, empirical or regression data models as well

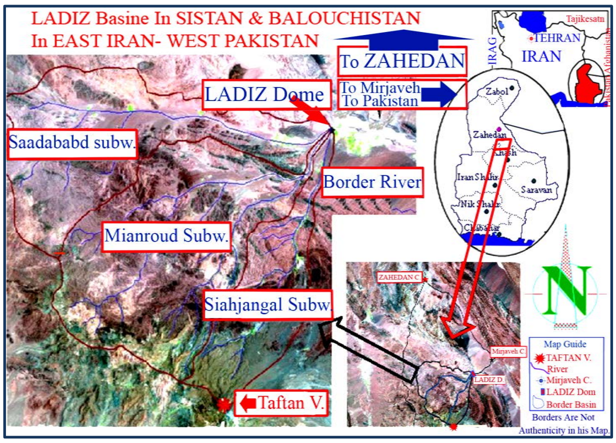

Figure 1. Location geology of the study area and in Sistan and Baluchistan province in Iran.

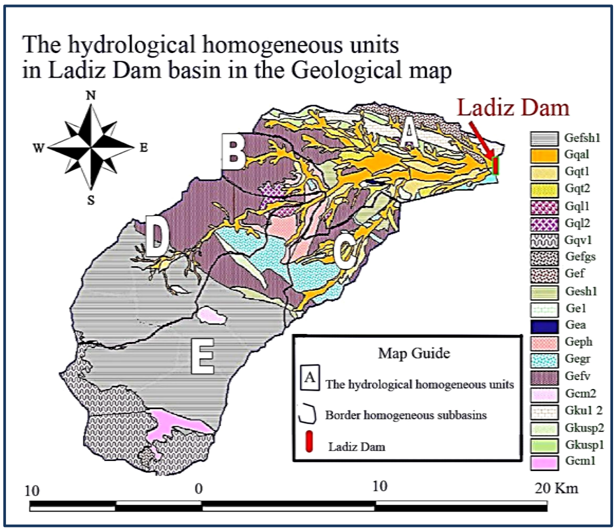

Figure 2. Dodar ladiz dam areageology map.

Table 1. Description of parts of a stone basin above the Dodar Ladiz Dam area.

Qal	Recent alluvium and river bed
Qt2	Younger alluvium plains
Qt1	Alluvial plain
Ql2	Younger terraces
Ql1	Older terraces
Qv1	Lower andesitic and dacitic flow of taftan volcano
Efgs	Grey to greenish grey greywacke to subgraywake sandstone, numulitic calcareous
Efsh	Light grey to greenish grey meta pelitic shale with lava flow of basalt and red shale
Ef	Dominantly sandstone and shale partly calcareous and phyllite (flysh type)
Esh1	Olive mudstone and shale
El1	Light grey to fossiliferous limestone
Ea	Amygdaloidal basin volcanic (Basalt and Andesite)
Eph	Red-parple phylithic with intercalations of red argillaceous sandstone
Egr	Greywacke-subgraywake and meta greywacke
Efv	Pale grey to pale greenish grey meta pelitic shale in association with abound ant lava flow of basalt
Ew	Wild flysh
Cm2	Coloured mélange
Kul2	Grey and dark grey globtruncana limestone
Kusp2	Spilitic volcanic rocks with/locally pillow structure
Kusp1	Spilitic volcanic rocks with pillow structure
Qt2	Younger alluvium plains
Qt1	Alluvial plain
Ql2	Younger terraces
Cm1	Coloured mélange (ultrabasic)

as conceptual models [3]. Significant differences in on various relationships and models are investigated to predict the amounts of erosion and sediment production in the targets, the required time and spatial scales in the area [3].

The important point is that in the great watersheds, partly due to massive accumulation of sediment in alongside of the river, such as flood plains, the total amount of annual precipitation will be shown lower than the rate of erosion in the basin [4].

Regional tectonic, volcanism and past weather convince us that erosion in the past has acted more severely in many large basins than what has been affected by different factors of weathering at the present time [5]. Many studies have illustrated the reverse relationship between the annual sedimentation volume and the rate of erosion in the watershed. In small watershed, short-term events are effective in deposit rates while in producing the large basins, erosion rates and sediment production are mostly affected by long-term processes [6]. In any case, whatever has been performed in the form of surveys on erosion and sediment will not meet the serious need in this area, because watershed conditions are in a way that it is often difficult to determine erosion and sediment production in the hydrological units. Due to these problems, one of the proposed methods in recent years is applying resourcing with a series of tracer minerals and determining the main sources of sediment production and the relative importance of each of them in sediment production in basin level [4]. Identification of the present erosion and determining basin sedimentation in different regions will not only make us to focus on activities related to preventing erosion and optimal allocation of funds, but it will also save the time for soil conservation programs and prevent severe soil erosion. Therefore, it is necessary to calculate and estimate the severity of erosion and the annual sediment production rate in the basin and provide a subtle prevention plan for it.

2. Methods and Materials

Sistan and Baluchistan province is located in South East of Iran. Mianrud River watershed area with 471.22 square kilometers is one of the most important sources of drinking and agricultural water supply in Mirjaveh town and its surrounding villages located in North East of Taftan volcano. From geological point of view, it is located in the Flysch structural zone of Eastern areas of Iran. Of stratigraphy and lithology views, four sets of color mélange, Cretaceous, Paleocene and Eocene Flysch, Taftan volcanic rocks and old and young Quaternary alluviums can be identified in this region. This area is one of the lowest rainfall areas with annual rainfall of 63.6 mm with a dry climate. Short-term and severe rainfalls which create vast floods have a very important role in Ladiz watershed. Mountainous areas with high gradients have expanded in south and southwest and from North West. They have extended to south and southwest areas of the watershed, due to the extension of the roughness, the altitude has increased and it has also increased the expansion of Taftan volcanic regions.

3. Identification of Homogeneous Units in Production of Sediment

The first step in developing a cost effective program management and erosion in the basin is identifying the factors and severity of erosion in the form of a series of homogeneous units [7]. In tense tectonic in the zone has brought up the of the rockyunits, so that it is possible to observe an independent Lithological unit with an identical composition, extent and out crops watershed levels. Therefore, homogeneous units were chosen in this area as the hydrological units. One of the advantages of this choice might be the fact that the results of the processes and involving factors in the erosion watershed have represented a final evaluation in their own hydrological units. On this basis, 5 hydrological units (A, B, C, D, E) were identified in the upstream basin of the dams (**Figure 3**).

The Calculation of the Accumulated Sediment in the Dam Reservoir

The volume of accumulated sediment in there servoir shows the rate of erosion and sediment transport in the watershed up stream of the dam during the construction period of the dam.

$$T_e = 100\left(1 - \frac{1}{1 + 2.075(c/A)}\right)$$

Since Dodar Ladiz reservoir (dam nutrition) has dried in late summer, the operations of mapping reservoir

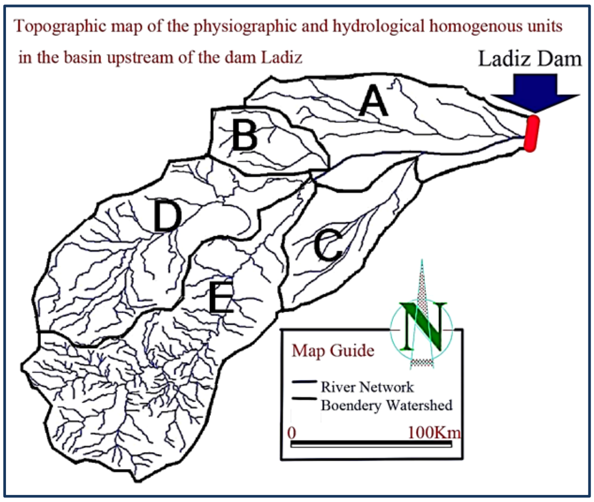

Figure 3. Separation of homogeneous units based on physiographic characteristics and hydrological conditions upstream Dodar Ladiz damwatershed.

sedimentation were performed in September 2009 after a one-year period of the dam operation.

By calculating the coefficients of obtained reservoir sediment using Moore *et al.* method (1960) [8], the upstream watershed deposition rate was achieved (**Table 2**).

Coefficient according to Mooreset up traps with the following equation is defined (reservoir capacity/1000 m^3 = C and Watershed area/km^2 = A).

4. Clay Mineralogy in Dodar Ladiz Dam Watershed

Due to fine clay minerals and possessing a negative charge that causes their suspension in flood situation and their diversity and abundance in sediments and also, their various physical and chemical properties, these minerals can be mentioned as sources in watershed are as for identifying regions which are under erosion.

Several researchers including the Wall and Walling (1976) [9], Wood (1978) [10], and Walling (2005) [4] have used clay minerals as source. In their researches the essential hypothesis in all studies has been the fact that due to the sweetness of river water and pH = 8.2 which is closet on eutral state, fine particles are not cohere Immediately and suspension time of diverse clay minerals in water and the particle size will not have any impact on the minerals distribution and sedimentation. On the other hand, no fundamental change will occur during floods and even after that in the composition of clay minerals.

The X-ray diffraction method (XRD) is used to study and identify the type of clay minerals and their percentage in the samples taken from different parts of the basin. In this research, the classification of clay minerals is based on the category of AIPEA Argils, AIPEA (Association International Pour Etude des, 1976).

Results obtained from testing the X-ray diffraction (XRD) are in four states:

1) Saturated with Ethylene Glycol;
2) Saturated with Mg;
3) 550˚ Temperature;
4) Saturated with K.

Four main groups of clay minerals including Kaolinite, Illite, Chlorite and Montmorionite indifferent amounts are seen in the studied samples (**Table 3**). The frequency rate of each clay mineral in the samples is calculated by using the proposed method of Moore and Reynolds (1989) [8].

4.1. Data-Mining

Statistical methods are between the best ways for dealing with data and extracting inferences. In those cases which it is probable to find a relationship between several variables (clay minerals) with the dependent variables (erosion rate) and it is also unclear to determine aggressive, independent and dependent variables. It seems wise to do some tests which analyze the relationships between some variables with a dependent variable simultaneously (**Figure 4**).

Table 2. Special results obtained from the deposition dam watershed are amapping using reservoir sediments (Mooreand *et al.* 1960).

Name of Dam	Sedimentation reservoir area (m^2)	Sedimentation reservoir in a one-year period (m^3)	Factor trap	Weight sediment reservoir (ton)	Area above the dam watershed (km^2)	Special deposition up stream dam watershed (m^3/km^2/year)	Special deposition dam upstream watershed (ton/km^2/year)
Dodar-e-Ladiz	558,796	698,495	89%	1047742.5	471.82	1663.4	2220.64

Table 3. Average values of clay minerals in the hydrological units Dodar dam and reservoir sediments.

Sub watershed	A	B	C	D	E	Reservoir Dam
Kaolinite	0.633	0.601	0.627	0.647	0.468	0.612
Iolite	0.225	0.248	0.238	0.271	0.283	0.249
Chlorite	0.086	0.151	0.089	0.079	0.132	0.067
Montmorionite	0.055	0/00	0.045	0.002	0.117	0.072

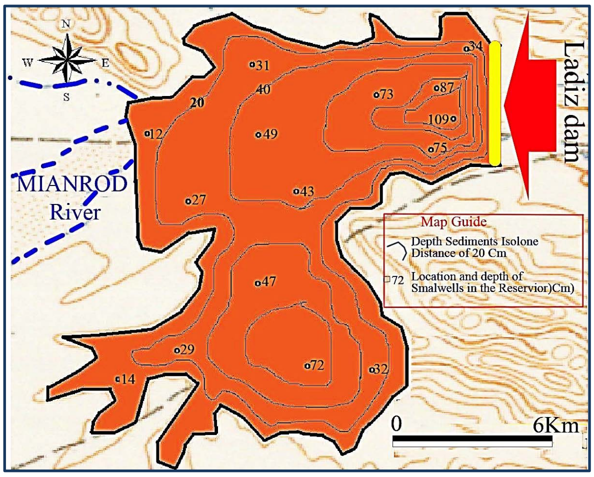

Figure 4. Expansion reservoir sediments at that location and Dodar Ladiz dam watershed and depth of small wells drilled in the reservoir sediments.

4.2. Multivariable Test

In order to study the changes associated with clay minerals in the watershed upstream of the Dodar dam. Multivariate Statistical Clustering Technique (Cluster Analysis) and Ward's Method were used [7]. Euclidean distance was also to calculate the distance. Based on the data in ANOVA table (**Table 4**), in which inter group and intra group communication of clay minerals available in the samples Dodar Ladiz dam watershed, F test was performed. There is a significant difference with %95 confidence ($P < 0.05$) between the frequency rates of clay minerals in the samples.

4.3. Hypothesistesting

Data used in the hypothesis tests of this study illustrate percentage and type of clay minerals in the reservoir and homogeneous units (clusters) in the upper basin. Thus, based on clay minerals clustering and hypothesis testing, the relationship between clay minerals per homogenous unit associated with clay minerals will be determined and this hypothesis will be repeated in any comparison. In hypothesis testing, zero hypotheses are rejected for all homogeneous and hydrological units and dam reservoir as well (**Table 5**).

Also, based on Kruskal-Wallis statistical test, we may conclude that the frequency percentage of Illite minerals identical among all hydrologic samples and dam reservoir, whereas the frequency percentage of Montmorillonite, Chlorite and Kaolinite minerals with 95% confidence in hydrological units and dam reservoir have significant differences (**Table 6**).

$$E = \sum_{t=1}^{T} \left\{ \left[\left| B_t - \left(\sum_{s=1}^{S} V_{st} P_s \right) \right| \right] \Big/ B_t \right\}$$

4.4. Calculation of Deposition Contribution of Homogeneous Units via Statistical Methods

For determining the share of product sediments for each homogeneous unit, the (2) equation (type of clay minerals = t, type of clay minerals in sediments within the reservoir = B_t, the amount of minerals in the same sub-basin = V_{st}, the share of each unit in the production of homogeneous Sediment = P_s, the number of homogeneous units = S, the number of clay minerals used in the origin navigation = T and the amount of relative error = E) is used that show in **Table 7** and **Figure 5**.

5. Discussion

The current study illustrates the applications and the ways of using clay minerals as mineral tracer for identifying the origin and evaluation of erosion rates using multivariate statistical test. The obtained results of this model

Table 4. ANOVA table for comparison of clay minerals in the basin is below the dam upstream (test statistic = df, degrees of freedom = F, significance level = Asymp. Sig.).

Sub watershed	A	B	C	D	E	Reservoir dam
Chi-Square	460.447	78.988	236.636	50.817	100.254	294.736
df	19	27	19	7	11	11
Asymp. Sig.	0.000	0.000	0.000	0.001	0.000	0.000

Table 5. Average clay minerals in the basin below based on Kruskal-Wallis test (test statistic x = chi-square, degrees of freedom = df, significance level = Asymp. Sig.).

Mineral clay	Kaolinite	Illite	Chlorite	Montmorionite
Chi-square	18.915	12.141	7.498	14.656
df	5	5	5	5
Asymp. Sig.	0.002	0.186	0.033	0/012

Table 6. Average separation of clay mineralsunder the basin based on Kruskal-Wallis test (test statistic x = chi-square, degrees of freedom = df, significance level = Asymp. Sig.).

Sub watershed	A	B	C	D	E	Reservoir dam
Chi-square	17.583	22.837	17.364	6.747	9.462	9.430
df	3	3	3	3	3	3
Asymp. Sig.	0.001	0.000	0.001	0.080	0.024	0.024

will be in accordance with the gained results if the desert observations represent a very high compliance. This procedure has several advantages than other methods including:

1) Applying clay minerals in the evaluation of erosion in order to achieve homogeneous units that can prove their erosion and sedimentation and fix the errors resulting from taking average at the watershed. In this way, it is possible to grade the basin in the best way. Also, it is helping in identifying those areas which are sensitive to erosion and finding spatial priorities for the executive actions to combat soil erosion.

2) Focusing on the study of homogeneous units prevents additional costs and repeated sampling such as establishing plots for determining the vegetation types or digging various profiles for evaluation and soil classification

3) Using clay minerals in the estimation procedure involves a careful study of erosion processes and other involved factors.

Therefore, it is expected to meet similar results between this evaluation and the amount of the transported sediment. But there remain some points to pause:

1) In this model, the base of the source are clay minerals sediments and thus major focus will be on fine-grain sediments; therefore, the basins with expanded gravels deposits will have an increased rate of error.

2) The exact cause of erosion is not recognized in this approach, whereas it is vital to identify and deal with erosion in the watershed.

3) Those materials which derive as the alluvial deposits from the erosion of upstream areas and sediment in low gradients areas in the sub-watershed deposits are not recognized precisely.

4) In this model, the basis of the obtained erosion rates in the watershed are in comparative form, *i.e.*

The total volume of erosion can be detected through comparing the watershed basins with higher and lower erosion rates, while the basis of erosion in a watershed should be studies and evaluated as an absolute check. Therefore, to reduce possible errors and increase confidence rate in using this model to determine rates of erosion in watershed areas Geomorphological and Sedimentological studies can help us considerably.

6. Conclusions

"Ladiz" basin is located in the South East of Iran, near Pakistan, part of the southern water basin of the country

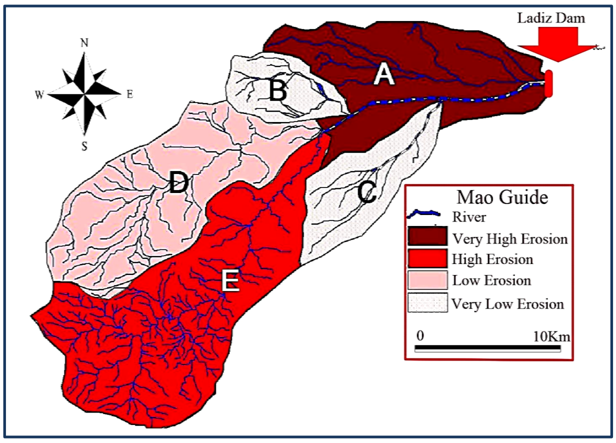

Figure 5. Map of erosion intensity in the hydrologic unit basin upstream dam Dodar Ladiz statistical models and methods using clay mineralsastracer.

Table 7. Determine the share of deposits produced by each of the unit in the basin of Dodar Ladiz dam using statistical methods.

Hydrologic units	A	B	C	D	E
Production share of deposits in per unit % (Ps)	0.448	0.0135	0.048	0.108	0.383
Production share of deposits in units (ton/km^2/year)	994.85	28.87	106.59	239.8	850.50

of Pakistan. "Dodar Ladiz" dam was built to control surface runoff and supply the water needed for farming and drinking residents of the area. Because of the water deposits within the water, reservoir dam was filled quickly by sediment. Huge quantities of sediment entering the reservoir dam are destroying the dam and causing economic costs of dam construction. This study has collected samples of sediment from river water supply and, by using statistical methods, tries to calculate and interpret the characteristics of sediment in the reservoir's basin.

Hydrological units were chosen as the homo-geneous units in the upstream watershed of Dodar Ladiz dam. Taftan volcanic pyroclastic units expanded in the west watershed are the most susceptible units to erosion and they possess an important potential for sediment production in this watershed. X-ray diffraction analysis, performed on the samples of the hydrologic units (Dodar Ladiz Dam), showed the presence of four main clay minerals including Kaolinite, Montmorillonite, Illite and Chlorite. Euclidian distance was used for clustering clay minerals and multi-variance cluster and also, statistical method was applied for studying the relationship of changes in clay mineral types in the upstream area. It was concluded that there is a meaningful difference between amplitude percentages of clay minerals of the samples with 95% confidence coefficients (P value < 0.05). Based on the statistical test of Kruskal Wallis, the groups were first divided and compared in order to distinguish mineral groups. In this case, the amplitude percentage of montmorillonite, chlorite and kaolinite minerals with a 95% confidence coefficient represents a meaningful difference between hydrologic units and the reservoir. Statistical analyses of data and study of clay minerals as a tracer for determining the erodibillity rate of the upstream area of Dodar Ladiz dam show that the maximum amount of erosion is present in the hydrologic area, *i.e.* a unit with the total surface area of 105.13 km^2. So, in order to avoid possible errors and to increase the confidence coefficient in applying this model for determining the erosional rate in the watershed areas, it is helpful to do further geomorphologic and sedimentological studies.

Although there is a good correlation between the results obtained from this mode with geomorphological, sedimentological and field observation, there are still some remaining points in this model for further surveys: 1) This model is based on fine-grain sediment and clay minerals; so in the watershed basin with coarser grain sediment, where most of the stream load is grave and the river is gravely bed, there are some chances of error in this type of the basin. 2) In spite of the importance of factors that cause erosion in the basin area, the cause of erosion is not considered in this method. 3) The resulting materials of the erosion from the upstream areas will be deposited in downstream and with gentle slope; therefore, they are not thoroughly analyzed.

The findings of this study show that before constructing any dam—which consumes large financial costs—comprehensive and detailed studies of climate, topography and topology, lithology, weathering and erosion, sedimentology and etc., should be done, using the newest information and scientific methods in all flowing rivers, seasonal rivers, semi dry rivers and even drying rivers in the basin area.

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