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Regression Analysis for Estimating Watershed Potentialities and Environmental Indicators Cover/Use Surface in Loukkos, Tangerois and Mediterranean Coastal Basin in Morocco

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Abstract: ***In domain of environmental science especially water resources discipline, the very interesting and challenging task is how to analyze, extract and visualize knowledge from large scale data sets. The recent evolution of science computer precisely web technology provides an important tool for data collection and analysis. This paper presents different scenarios of modeling technics represented by simple linear regression analysis applied to environment indicators data set up to 14.9 million lines analyzed and extracted from satellite image of Loukkos, Tangerois and Mediterranean Coastal (LTMC) Basin in Morocco. The purpose of this work is to estimates regression model's parameters, using an optimization method represented by R function of simple linear regression so that the error of the sum for multiple and adjusted R-square is minimized. In this study an application on real data set analyzed and extracted from classified satellite image of (LTMC) basin. The classification of this satellite image contains different class of data sets such as: Agglomeration, dams, watercourses, crop lands, bare soils and forests…etc. The regression analysis is very important statistics method for analysis that enables the characterization of relationships among multiple relevant risk factors; also it enables the calculation of risk scores. The purpose of statistical evaluation of environmental indicators data set is often to describe relationships between two variables or among several variables. For example, in our case study one would like to know potentiality and cover/user surface of environmental indicators as cited. Y is The variable to be explained, or alternatively, the response variable, in our real data set represented by Altitude; and one or more variable that explain it, is called independent variable or predictor variable X in our real data set represented by combined surface area.***

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Index Terms**:** ***Simple Linear Regression, R, Environmental indicators distribution, Satellite image, Watershed potentialities.***

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I. NTRODUCTION

Environmental, economic and social aspects are among the problems that impact on level of basin sustainability. The development of these aspects increase impoverishment of natural resources in basin and exert constraints on environmental indicators [1] such as: vegetation, soils, watershed, crop lands and dams.

To facilitate the management of these natural resources it needs to improve the adoption of new technological solutions. In the last few years there were various scientific researches and different strategies in this area to reach the goal. Among these strategies: making efficient decision to improve the socio-economic level and enhance sustainable development using hypsometrical approach [2], automating of this hypsometrical approach as decision support system, integrating environmental indicators, assessment of distribution semi-arid areas covered by vegetation and soil [3].

As mentioned above the target of this paper is to estimates regression model's parameters of environmental indicators cover/use surface in basin of Loukkos, Tangerois and Mediterranean Coastal (LTMC) basin, using an optimization method represented by R function of simple linear regression so that the error of the sum for multiple and adjusted R-square is minimized. In the field of statistics, the linear regression is considered as linear approach that can be used to evaluate the relationship between the dependent variable and other independent variable or different independent variables.

The data set obtained in this last work is our starting point for our current work. We have used data set up to 14.9 million lines of environmental indicators analyzed and extracted from satellite image of LTMD basin. The data includes various studied parameters such as: pixel id, position X, position Y, Altitude (position Z), combined surface area. In our case study we limit the parameter in two variables which are the altitude and the combined surface area to apply the simple linear regression.

The structure of this work is organized as following: In the following section of this paper it concerns methodology and materials it provides an overview of Theoretical Background of Applied modeling techniques such as simple linear regression, study area and available data set. The second section presents results and discussion. The last section conclude this work and gives perspectives.

II. METHODOLOGY AND MATEROALS

2.1 Study area overview

LTMC basin is the experimental area it characteristic a great shortage of natural resources. is located at the upper of Morocco map within diffirents provinces: Tangier, Tetouan, Larache and partially those of Chefchaouen represented by 65%, Al Hoceima 61%, Kenitra 33%, Sidi Kacem 9% and Taza 2%. Tangier is a major city in northwestern Morocco, is located at the western entrance to the Strait of Gibraltar [4].

Loukkos basin constitutes as countryside and most developed in this study area.

According to [5], LTMC covers 13000 km² more or less 1.6 percent of the total surface of Morocco, it extends in the west by the Atlantic Ocean on 140 Km, in the north represented by the Mediterranean border for almost 260 Km, in the east represented by Moulouya basin. See the following Fig. 1

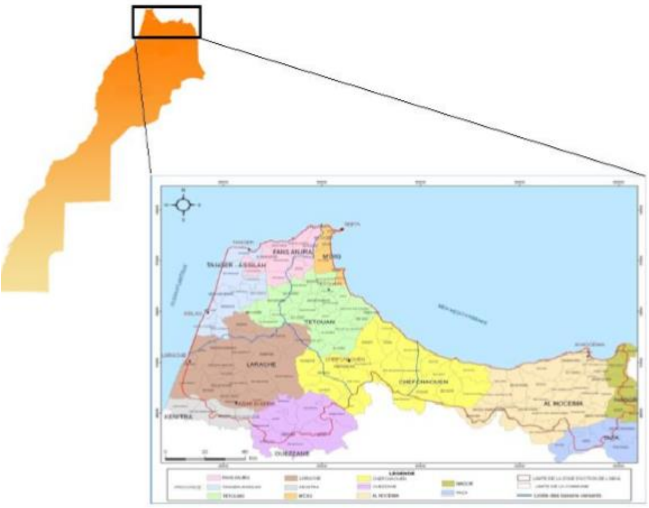

Fig. 1. Location of Loukkos, Tangerois and Mediterranean coastal basin [5]

LTMC basin constitutes an living site for several environmental indicator [6] such as: vegetation, demography, urbanization, soils, water... The area has considerable renewable water potential, about 4 billion m3 / year as an average contribution.

According to [5], the average annual inflow of surface water in the zone amounts to 3.600 Mm3 / year with a strong inter-annual irregularity. The observed maximum is nearly three times the average modulus, while the minimum hardly exceeds 15%. The surface water resources mobilized amounted to 912 million cubic meters, of which:

- 896 million cubic meters of volumes regulated by dams, i.e 12% of the volume regulated by dams in Morocco.
- 16 million cubic meters taken in the course of the water, ie 2% of the volume mobilized in surface water in the basin (a very low proportion in Morocco, where the average exceeds 18%).

2.2 Theoretical Background of Applied Models

2.2.1 Simple linear regression

Analyzing different issues related to prediction, evaluation, size, power or precision using multiple linear regression, regression analysis of a Photovoltaic system in Ouarzazate polydisciplinary faculty [8]. It is recommended to understand by first the simple linear regression context [7]. In the statistical domain, simple linear regression model is the most frequently cited [9].

With linear regression, we evaluate data points of one variable represented by the criterion variable referred to as Y from the points of another predictor variable referred to as X. This analysis regression called simple when there is just only one independent variable [10].

We can say that it is very easy to interpolate between the points to make relationship or what we call correlation between this data points when the variable Y is linearly related to X as independent variable. Suppose that we have a set of data pairs represented as follows: (X_1, Y_1), (X_2, Y_2)... (X_n, Y_n). The goal here is to find the right line regression or what we call fitted line.

Mathematically the calculated values are:

$$Y_i = \alpha + \beta X_i \quad \text{for} \quad i=1,\dots, n \qquad (1)$$

Where: Y_i = the calculated linear value.
X_i = the experimental value.

Then the residuals ri can formulated as follows:

$$ri = Yi - \alpha - \beta Xi \quad \text{for } i = 1,\dots,n \qquad (2)$$

According to the equation above (1) the primary objective here is to find the values of α and β in order to find the most appropriate straight line. The strategic trick here is to position the values of α and β in order to give a straight line by minimizing the sum of the residuals ri. Whatever the positive or negative sign, if we get an inappropriate error that means that the criterion is inadequate. To remedy this problem, the absolute value of the sum of these errors is minimized by selecting the values of α and β. To have an optimal fit we use another criterion called minimax [11] using this last criterion we minimize the maximum distance at which a pair of data deviates from the calculated line. Unfortunately this minimax criterion gives a large error in a single point. An optimal criterion that has advantages for that it eliminates all the disadvantages of the criterion mentioned previously, among these advantages, for a given data set we find a unique line result. This criterion consist to minimize the sum of the squares of residuals [12].

As we cited above the goal of regression analysis is to determine the constant in correlation between variables. Let's considered simple case to demonstrate this equation $Y= \alpha + \beta X$ to fit obtained experimental data of xi and Yi.

Let's define the residuals or error as following: $r_i = Y_i - x_i$

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If we apply the optimal criterion explained above, the sum of the squares should be minimum and his equation (3) or (4) defined as follows:

$$S = r_1^2 + r_2^2 + \ldots.. + r_n^2 = \sum_{i=1}^{n} r_i^2 \quad (3)$$

Or

$$S = \sum_{i=1}^{n} \{Y_i - [\alpha + \beta\,(x_i)]\}^2 \quad (4)$$

To give a minimum for the sum, the derivative of equation (3) or (4) is equal to zero. In addition the coefficients α and β should satisfy the condition of optimality.

$$\frac{\partial S}{\partial \alpha} = \sum_{i=1}^{n} \{-2\}\{Y_i - [\alpha + \beta\,(x_i)]\} = 0 \quad (5)$$

$$\frac{\partial S}{\partial \beta} = \sum_{i=1}^{n} \{-2\,(x_i)\}\{Y_i - [\alpha + \alpha\,(x_i)]\} = 0 \quad (6)$$

We observe two unknowns coefficients α and β in equations (5) and (6). So we can solve for a unique set of coefficients.

Let's divide (5) and (6) by {-2} and result should be as follows:

$$\alpha\, n + \beta \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} Y_i \quad (7)$$

$$\alpha \sum_{i=1}^{n} x_i + \beta \sum_{i=1}^{n} x_i x_i = \sum_{i=1}^{n} x_i Y_i \quad (8)$$

Otherwise, from a matrix notation, the result above (7) and (8) became as follows: M * a = N
Where: "a" is vector column.
M and N are two matrixes.
or

$$\begin{bmatrix} n & \sum_{i=1}^{n} x_i \\ \sum_{i=1}^{n} x_i & \sum_{i=1}^{n} x_i x_i \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{n} Y_i \\ \sum_{i=1}^{n} x_i Y_i \end{bmatrix} \quad (9)$$

Using the function of matrix process capability, "a" can be solved.

2.3 Environmental Indicators Practice Dataset

Test dataset used in this work up to **14.9 million lines**, they are generated by a system developed and automated in our previous work entitled Automated Hypsometrical Approach, Integrating Environmental Indicators. In this section we describe the data and model we use in order to produce comparable results applying simple linear regression model as explained above. Data used for this experiment case study are analyzed and extracted from classified satellite image [13] of LTMC basin.

The following tables represent the results obtained by applying this automated system, we cited some examples: Agglomeration contains up to **421 901 rows** as shown in Table 1, watercourses contain **289 909 rows** (Table 2.), forests **2 562 144 rows** (Table 3.), bare soil **6 018 580 rows** (Table 4.) and crop lands up **5 235 789 rows** (Table 5.) These tables contain different parameters like as: Id pixel, position X, position Y, position z (altitude) and combined surface area.

Table.1 Agglomeration

Id Table	Id pixel	Position X	Position Y	Position Z (Altitude)	Combined surface area
1	43	283305	3.97796e+006	0	2.41299
2	43	283155	3.97793e+006	0	2.41299
3	43	283245	3.97793e+006	0	2.41299
…	…	…	…	…	…
295599	43	426645	3.89033e+006	34	14.7155
295600	43	426675	3.89033e+006	35	14.9343
295601	43	426705	3.89033e+006	35	14.9343
295602	43	426735	3.89033e+006	36	15.1319
…	…	…	…	…	…
421897	43	410205	3.84254e+006	1546	37.757
421898	43	410235	3.84254e+006	1538	37.7514
421899	43	410265	3.84254e+006	1530	37.7455
421900	43	410205	3.84251e+006	1558	37.7673
421901	**43**	**410235**	**3.84251e+006**	**1549**	**37.7596**

Table.2 Watercourses

Id Table	Id pixel	Position X	Position Y	Position Z (Altitude)	Combined surface area
1	1	283275	3.97799e+006	0	0.49356
2	1	283305	3.97799e+006	0	0.49356
…	…	…	…	…	…
101761	1	319785	3.90815e+006	116	13.33
101762	1	320535	3.90815e+006	52	8.60283
101763	1	320565	3.90815e+006	58	9.16614
101764	1	320595	3.90815e+006	68	10.0943
…	…	…	…	…	…
289905	1	413985	3.84275e+006	1304	25.4965
289906	1	411555	3.84269e+006	1300	25.489
289907	1	411585	3.84269e+006	1315	25.5191
289908	1	411465	3.84257e+006	1332	25.5561
289909	**1**	**411465**	**3.84254e+006**	**1354**	**25.6001**

Table.3 Forests

Id Table	Id pixel	Position X	Position Y	Position Z (Altitude)	Combined surface area
1	5	283455	3.97754e+006	0	4.70979

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2	5	286395	3.97724e+006	0	4.70979
…	…	…	…	…	…
1537557	5	253005	3.88787e+006	417	102.145
1537558	5	253035	3.88787e+006	408	100.204
1537559	5	253065	3.88787e+006	381	94.2192
1537560	5	253095	3.88787e+006	375	92.8936
…	…	…	…	…	…
2562140	5	410955	3.84242e+006	1371	207.343
2562141	5	410985	3.84242e+006	1363	206.68
2562142	5	411015	3.84242e+006	1357	206.165
2562143	5	411045	3.84242e+006	1357	206.165
2562144	**5**	**411165**	**3.84242e+006**	**1346**	**205.232**

Table.4 Bare soil

Id Table	Id pixel	Position X	Position Y	Position Z (Altitude)	Combined surface area
1	4	283155	3.97799e+006	0	6.79617
2	4	283185	3.97799e+006	0	6.79617
…	…	…	…	…	…
2106867	4	259665	3.90956e+006	271	202.68
2106868	4	259725	3.90956e+006	304	222.618
2106869	4	259755	3.90956e+006	304	222.618
2106870	4	259965	3.90956e+006	267	200.374
…	…	…	…	…	…
6018576	4	411135	3.84242e+006	1355	522.342
6018577	4	411285	3.84242e+006	1338	520.445
6018578	4	411315	3.84242e+006	1348	521.569
6018579	4	411345	3.84242e+006	1374	524.321
6018580	**4**	**411375**	**3.84242e+006**	**1388**	**525.682**

Table.5 Crop lands

Id Table	Id pixel	Position X	Position Y	Position Z (Altitude)	Combined surface area
1	3	283215	3.97826e+006	0	6.5934
2	3	283245	3.97826e+006	0	6.5934
…	…	…	…	…	…
1832817	3	264945	3.90959e+006	286	273.959
1832818	3	264975	3.90959e+006	292	277.126
1832819	3	265095	3.90959e+006	310	286.136
1832820	3	265125	3.90959e+006	316	288.996
…	…	…	…	…	…
5235785	3	410205	3.84242e+006	1600	467.03
5235786	3	410265	3.84242e+006	1588	466.629
5235787	3	411195	3.84242e+006	1342	453.538
5235788	3	411225	3.84242e+006	1341	453.467
5235789	**3**	**411255**	**3.84242e+006**	**1344**	**453.68**

III. RESULTS AND DISCUSSION

3.1 Studied Variables using R

In this work, different methods was applied using R software [14], to validate simple linear regression model in order to make generalized deduction to the same target of independent variable, in our case study by combined surface area but with different environmental indicator. As well-known R is free software specialized in the field of statistical and graphical computing. It runs on variety of Operating systems platforms [15].

The variable to be explained or the dependent variable Y, in our real data set represented by Altitude; and other variable, called independent variable or predictor variable X in our real data set represented by combined surface area. In this section we take twos variable as practice data for each table:

Y: Position Z represented by Altitude (m), the dependent variable of our model to study.

X: combined surface area (km²), the independent variable.

Let define linear regression model: $Y = \alpha + \beta X$

We take some examples of environmental indicator to estimate cover/use surface, and water courses potentialities in LTMC basin such as: agglomeration Fig. 2, water courses Fig. 6, forests Fig. 10, bare soils Fig. 14 and crop lands Fig. 18.

There are some of R functions used to estimate and test:

- lm (altitude ~ combined_surface, data)
- summary (altitude ~ combined_surface, data)
- plot (altitude ~ combined_surface, data)

The output tables of the function lm in R, gives the coefficients α, β, R2 and p-value, that tell us how well a model represents given data for each example see Table 6, 7, 8, 9 and Table.10.

Residuals vs. Fitted plot illustrated in Fig. 8, Fig. 12, Fig. 16 and Fig. 20, shows if residuals have non-linear patterns.

Normal Q-Q plot illustrated in Fig. 3, Fig. 7, Fig. 11, Fig. 15 and Fig. 19, shows if residuals are normally distributed.

Residuals vs. Leverage plot illustrated in Fig. 4, Fig. 9, Fig. 13, Fig. 17 and Fig. 21, Used to find the cases of influence, in the linear regression analysis all the values have no influence. This means that the results would not be very different if we excluded or included them from the regression analysis.

Table.6 agglomeration estimated coefficients

Coefficients	Estimated	Std. Errror	T - value	pr value
Intercept	-207.078	**0.62893**	-329.3	<2e-16 ***
Combined surface area	20.18925	0.02861	705.6	<2e-16 ***

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Table.7 agglomeration result coefficients summary

Residual standard error: 199.6 on 421899 degrees of freedom				
Multiple R-squared	Adjusted R-squared	F-statistic	DF, p-value	
0.5413	0.5413	4.979e+05 on 1 and 421899	< 2.2e-16	
Residuals:				
Min	1Q	Median	3Q	Max
-181.5	-134.88	-49.62	74.09	1581.47

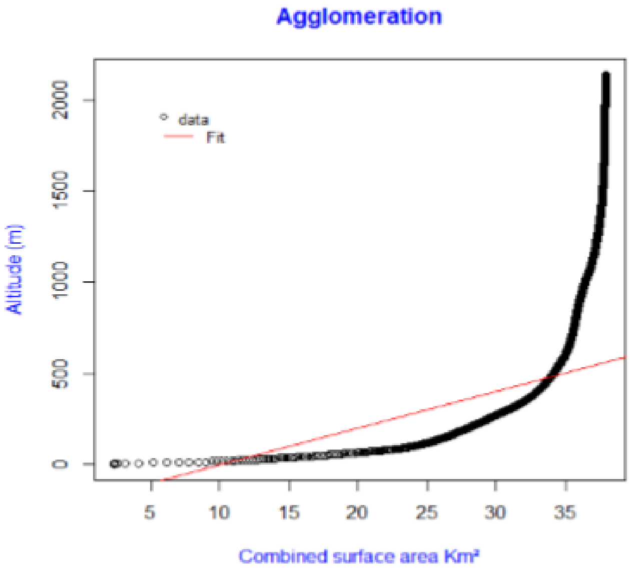

Fig. 2. Agglomeration regression result

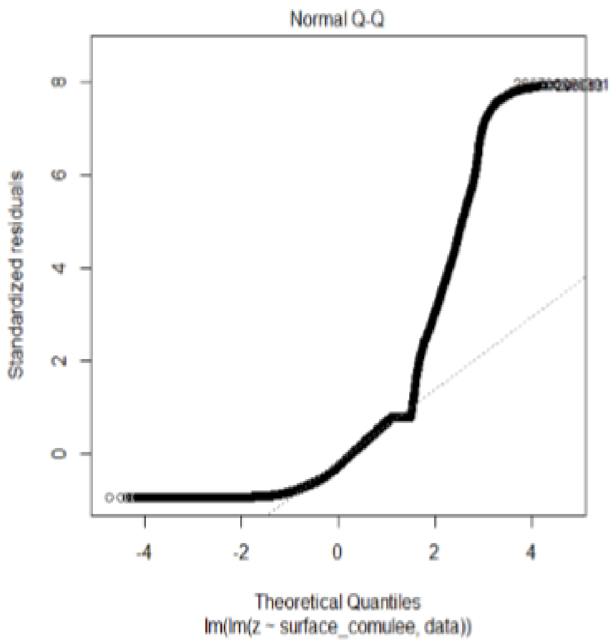

Fig. 3. Agglomeration theoretical Quintiles

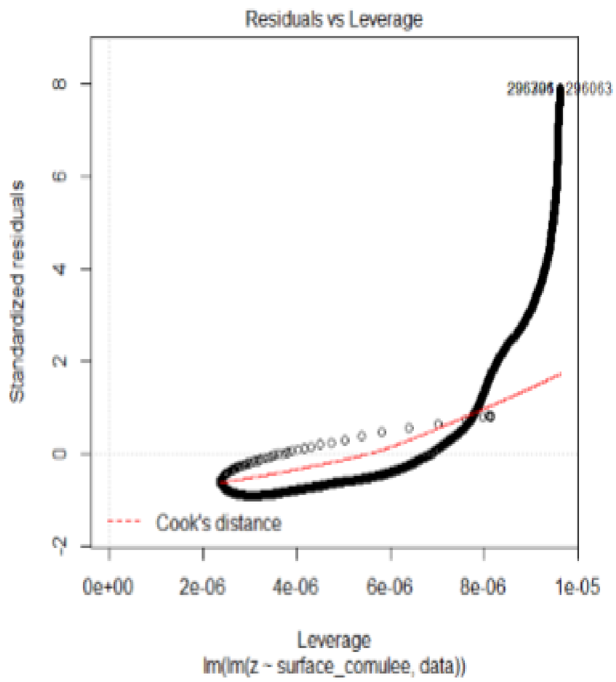

Fig. 4. Residuals vs Leverage of Agglomeration

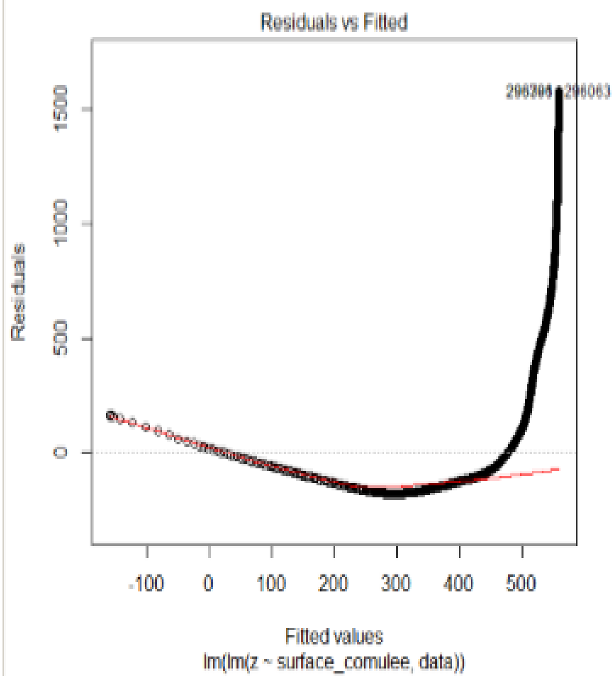

Fig. 5. Residuals vs Fitted of Agglomeration

Table.8 agglomeration estimated coefficients

Coefficients	Estimated	Std. Errror	T - value	p-value
Intercept	-230.66567	0.71071	-324.6	<2e-16 ***
Combined surface area	37.34219	0.04712	792.5	<2e-16 ***

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Table.9 agglomeration result coefficients summary

Residual standard error: 189.6 on 289907 degrees of freedom			
Multiple R-squared	**Adjusted R-squared**	**F-statistic**	**p-value**
0.6842	0.6842	6.281e+05 on 1 and 289907	< 2.2e-16

Residuals:				
Min	**1Q**	**Median**	**3Q**	**Max**
-176.15	-145.63	-50.75	94.36	1394.34

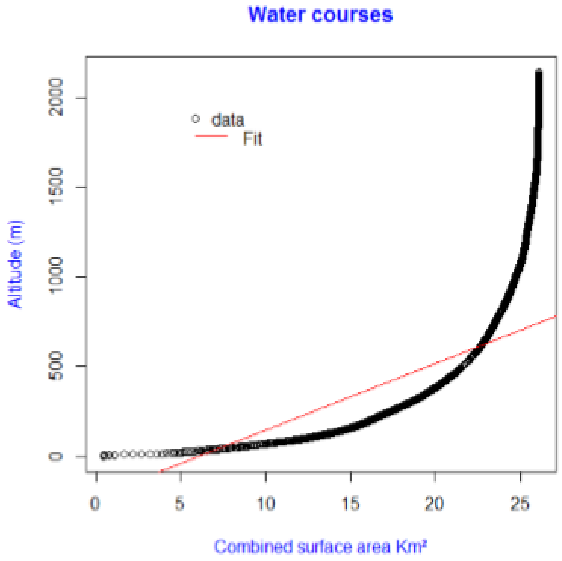

Fig. 6. Water courses regression result

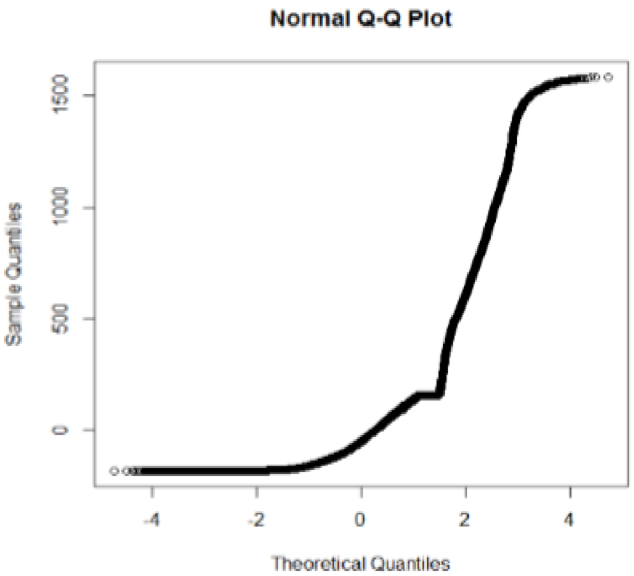

Fig. 7. Theoretical Quintiles of Water courses

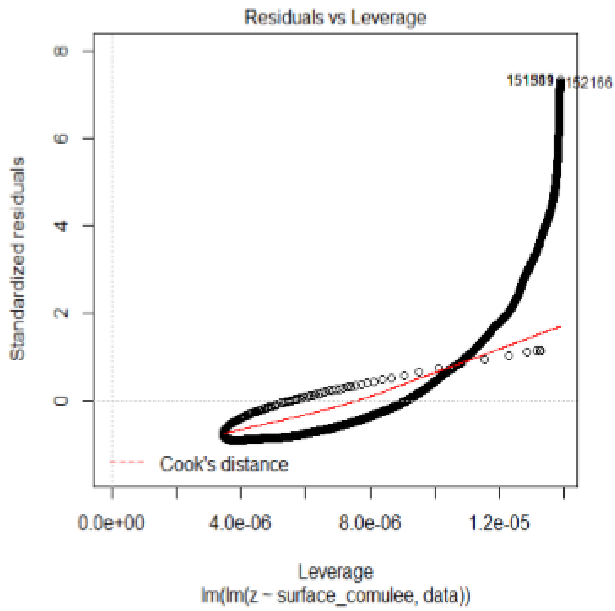

Fig. 8. Residuals vs Leverage of Water courses

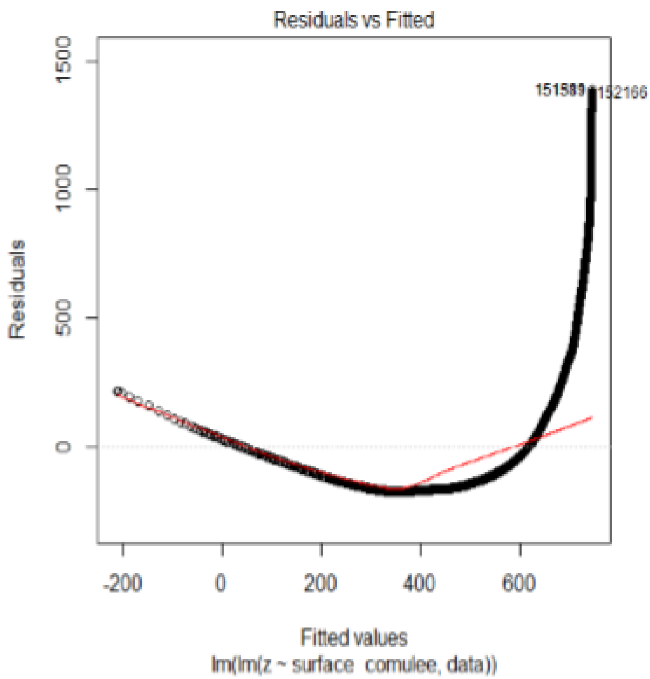

Fig. 9. Residuals vs Fitted of Water courses

Table.10 Forests estimated coefficients

Coefficients	Estimated	Std. Errror	T - value	p-value
Intercept	-1.906e +02	1.564 e-01	-1219	<2e-16 ***
Combined surface area	37.3421 9	1.174 e-03	5940	<2e-16 ***

Table.11 Forests result coefficients summary

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Residual standard error: 124.9 on 2562142 degrees of freedom			
Multiple R-squared	Adjusted R-squared	F-statistic	DF, p-value
0.9323	0.9323	3.528e+07 on 1 and 2562142	< 2.2e-16

Residuals:				
Min	1Q	Median	3Q	Max
-159.47	-117.41	-5.79	89.79	702.35

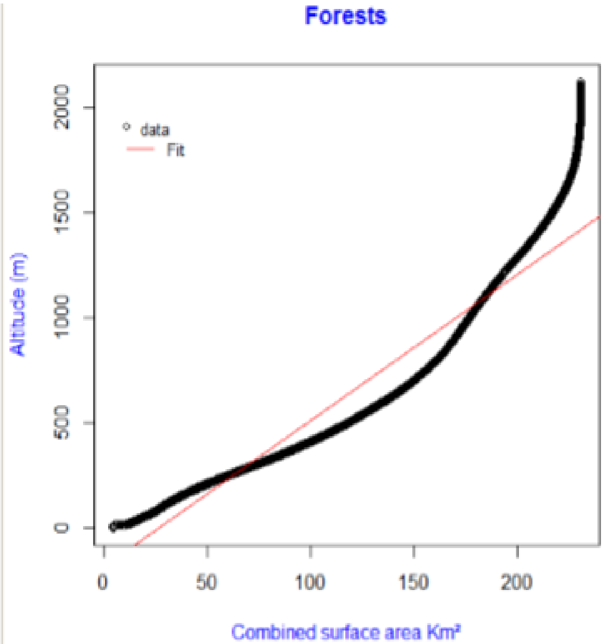

Fig. 10. Forests regression result

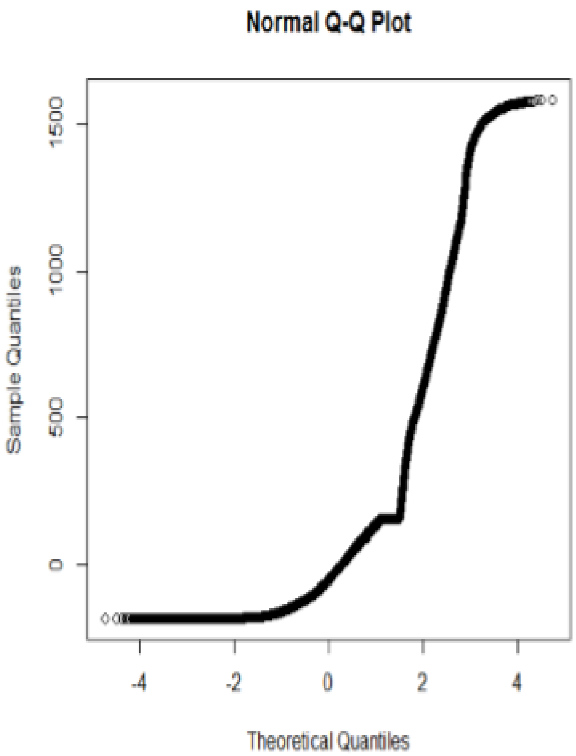

Fig. 11. Theoretical Quintiles of Forests

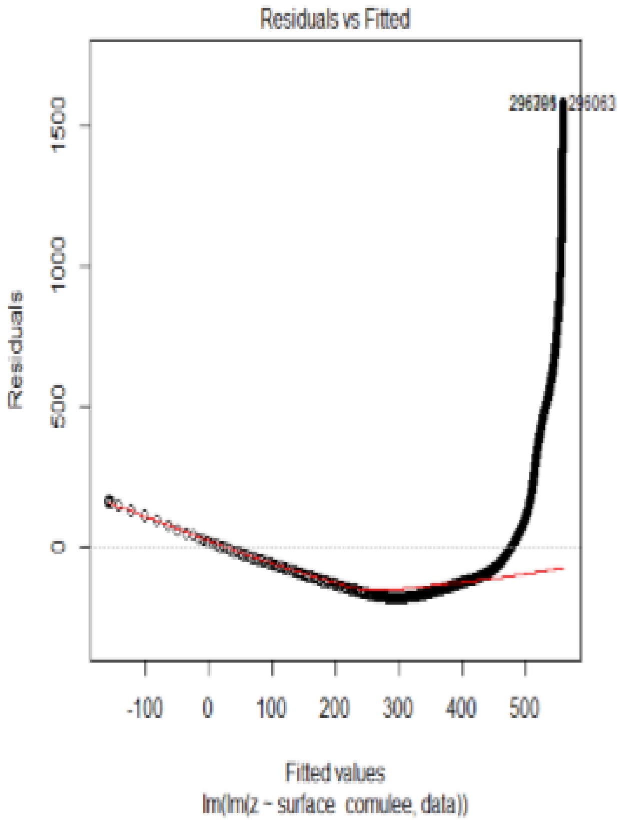

Fig. 12. Residuals vs Fitted of Forests

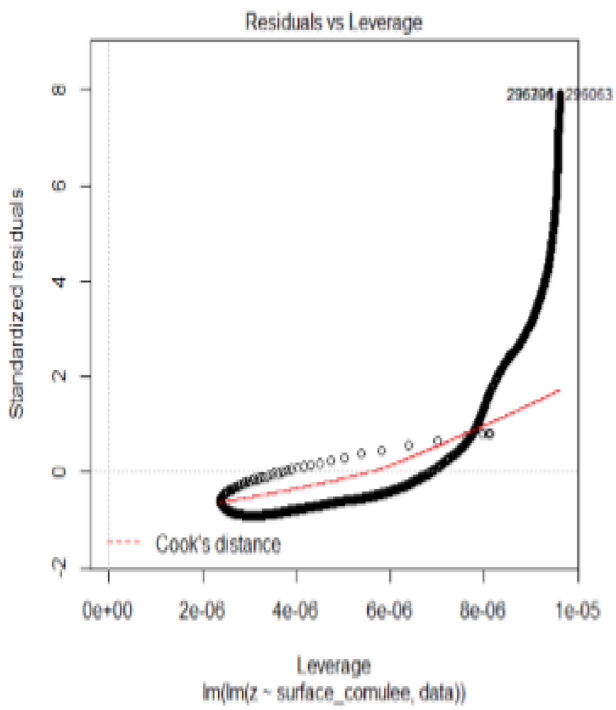

Fig. 13. Residuals vs Leverage of Forests

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Table.12 Bare soils estimated coefficient

Coefficients	Estimated	Std. Errror	T - value	p-value
Intercept	-1.801e +02	9.407 e-02	-1914	<2e-16 ***
Combined surface area	37.3421 9	1.174 e-03	8268	<2e-16 ***

Table.13 Bare soils estimated coefficient

Residual standard error: 124.9 on 2562142 degrees of freedom				
Multiple R-squared	Adjusted R-squared	F-statistic	DF, p-value	
0.9323	0.9323	3.528e+07 on 1 and 2562142	< 2.2e-16	
Residuals:				
Min	1Q	Median	3Q	Max
-159.47	-117.41	-5.79	89.79	702.35

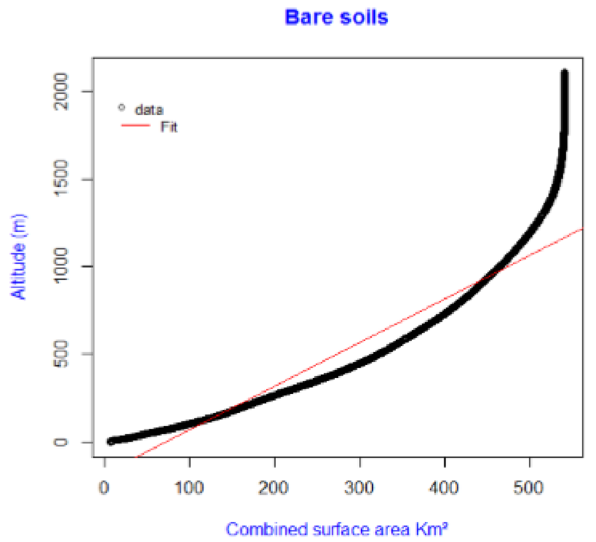

Fig. 14. Bare soils regression result

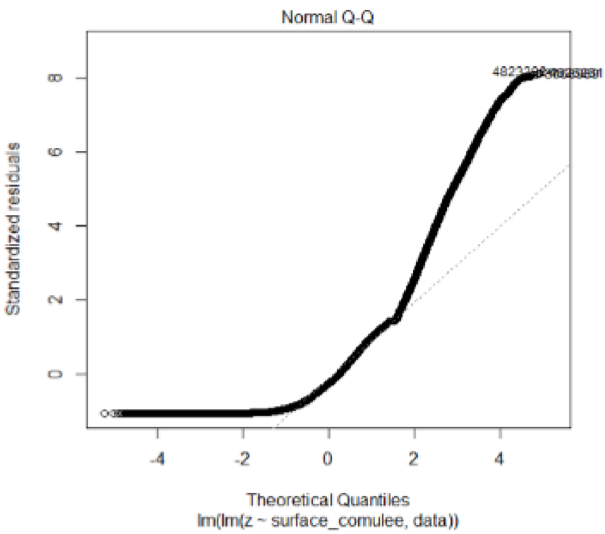

Fig. 15. Theoretical Quintiles of Bare soils

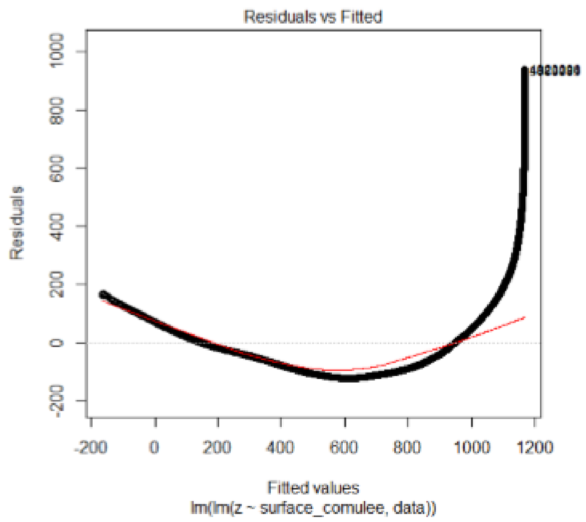

Fig. 16. Residuals vs Fitted of Bare soils

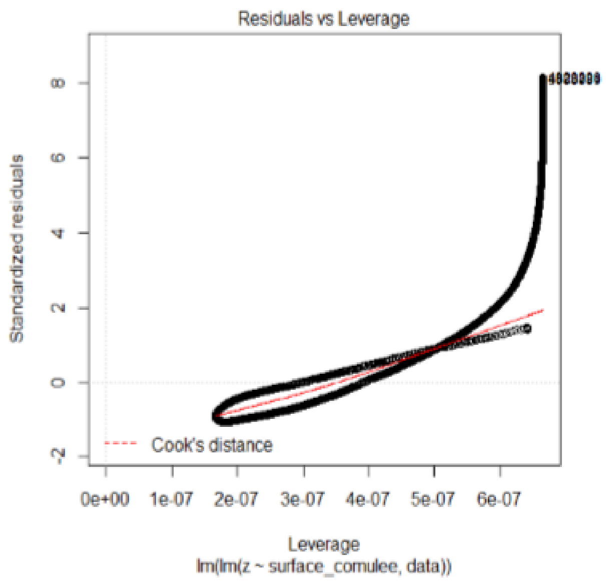

Fig. 17. Residuals vs Leverage Bare soils

Table.14 Crop Lands Estimated Coefficients

Coefficients	Estimated	Std. Errror	T - value	p-value
Intercept	-2.459e +02	1.609 e-01	-1528	<2e-16 ***
Combined surface area	2.608e+ 00	5.910 e-04	4413	<2e-16 ***

Table.15 Crop lands estimated coefficients

Residual standard error: 183.4 on 5235787 degrees of freedom				
Multiple R-squared	Adjusted R-squared	F-statistic	DF, p-value	
0.7881	0.7881	1.948e+07 on 1 and 5235787	< 2.2e-16	
Residuals:				
Min	1Q	Median	3Q	Max
-196.18	-152.43	-44.68	89.79	702.35

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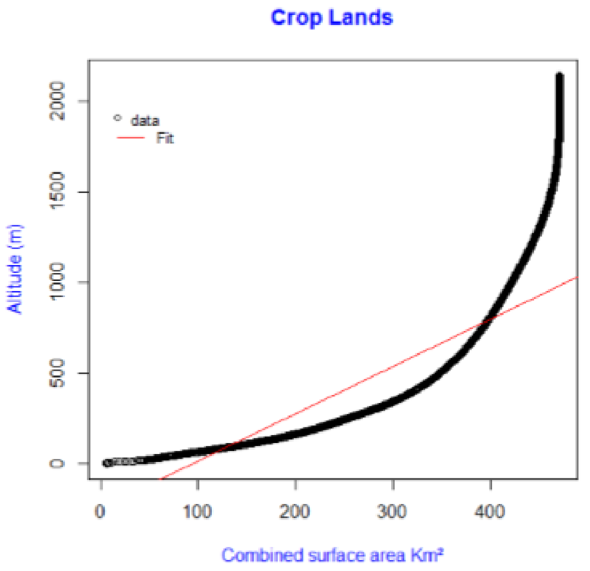

Fig. 18. Crop lands regression result

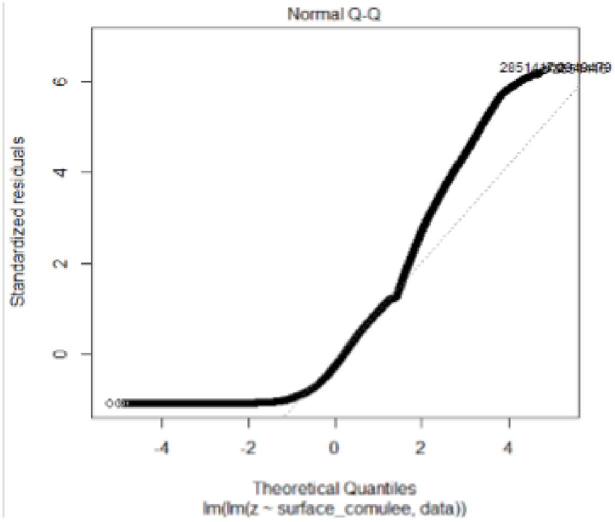

Fig. 19. Theoretical Quintiles of Crop lands

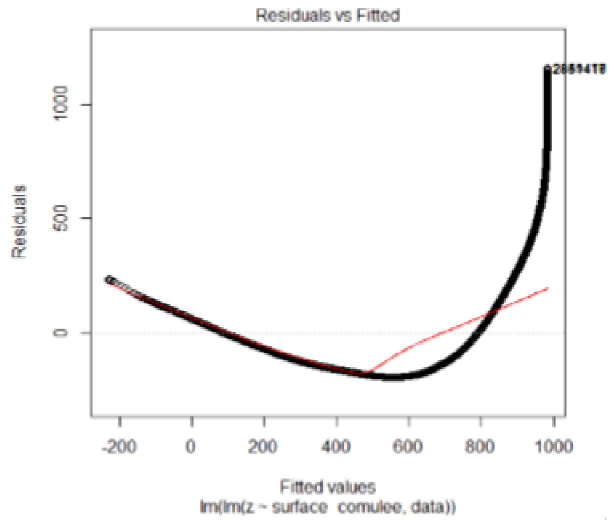

Fig. 20. Residuals vs Fitted of Crop lands

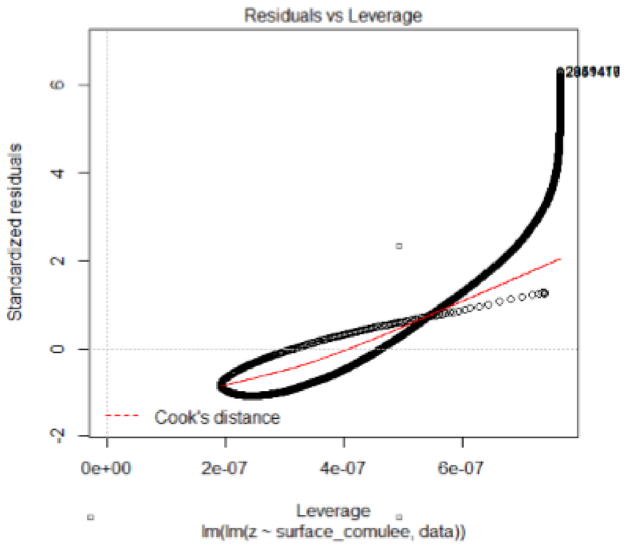

Fig. 21. Residuals vs Leverage of Crop lands

IV. CONCLUSION

According to results obtained above, the simple linear regression model applied can be used to estimate environmental indicators cover/use surface and watershed potentialities in Loukkos, Tangerois and Mediterranean Coastal Basin in Morocco. We observe that the R-squared and adjusted R-squared value are higher in all results obtained above. Thus, all R coefficients of correlation values are near 1, it means that exist a strong correlation between altitude and combined surface area.

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