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The Assessment of the Soil Erosion Intensity and Runoff in the River basin of ArbaaAyacha, Western Rif. Morocco.

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Abstract- This study reflects the use of the Erosion Potential Method (EPM) embedded in the Intensity of Erosion and Outflow model (IntErO) in the River basin of ArbaaAyacha, as a first application in the Moroccan territory to show its reliability for the estimation of the soil losses in the grounds and the streaming. This model required for first a mapping of the factors of hydric erosion, such as the land use, the type of ground, the lithology, the topography and the climatic and meteorological distribution of the data. The integration of the restart of this steep in the IntErOmodel allows the evaluation and the calculation of the streaming and the contribution of sediment in the studied area. The obtained result shows that the value of the Coefficient of the river basin erosion Z is 0.694, this value indicates that the river basin belongs to an III destruction category. The strength of the erosion process is medium, and according to the erosion type, it is mixed erosion. The maximal outflow from the river basin Qmax was predicted in 113.72 m^3s^{-1}, (incidence of 100 years). Finally the Real soil losses per km^2 are estimated to 228.94 $m^3 km^{-2}$ year and this value indicates, according to Gavrilovic, that the river basin belongs to the V category. This study has shown that IntErO model can be a useful tool for researchers in the calculation of runoff and sediment yield at the river basins level in the Western Rif of Morocco.

Index Terms: Soil erosion, Runoff, IntErO, ArbaaAyacha, Rif, Morocco.

I. INTRODUCTION

The degradation and the decrease of the quality of grounds in Morocco do not stop becoming more marked, especially in the studied region. The latter is known by these morphological characteristics, lithological and climatic predisposing the enormous extension of the various forms of hydric erosion. The impact is sometimes catastrophic forthe environment and the economy,changing the land use settings, causing the soil loss and its organic matter and the capacity of retention of the ground [1]and hydraulic structures, as well as progressive loss of the fertility of grounds and sometimes their contamination. Morocco feelsa pressing need for evaluation of the effects of the erosion on the soil productivity elaborating better strategies of its soils preservation[2]. Several methods and models were applied in various ponds hillsides of the Moroccan territory generally, and in the Rif in particular. The most recent studies demonstrate high vulnerability of the soils of Rif caused by the erosion processes [3]**.** Among these models and methods we quote USLE: Universal Soil Loss Equation of Wischmeier and Smith [4];WEPP: Water Erosion Prediction Project [5]; SWAT: Soil and Water Assessment Tool [6];PAPRAC:Priority Actions Programme Regional Activity Centre [7]; methods based on radionuclides[8]; [9];[10]and others. Yet the application of all these models are expensive and require a long interval of time to be applied [11],what is not always well received by the institutions and services in charge of fight against erosion. The interventions should be fast and thus the studies of erosion should be also sold in a lapse of the very short time. The Erosion Potential Method (EPM) showed its reliability and speed in the evaluation of the runoff and soil erosion intensity [12]especially for small watershed of average size and with short streams means,like the studied the ArbaaAyacha River with a surface of 199.9 km^2, and the mean length of the stream, lv, of 33.5 km. For the assessment of the Soil Erosion Intensity and Runoff in the River basin of ArbaaAyacha we used the program package IntErO (Intensity of Erosion and Outflow) [13] with the EPM method integrated into the algorithm of this computer-graphic model.Thisresearch of soil erosion processes at one of our watershedsof ArbaaAyacha is the first application of IntErO model and EPM methods in the Moroccan territories and we are with the position that it will serve as a useful, fast and reliable approach for estimating and calculating of runoff and soil erosion intensity, and it can be a basic document for managers in studies of phenomena of erosion in other watersheds, similar to the River basin of ArbaaAyacha of Morocco.

II. STUDY AREA

The watershed of ArbaaAyacha (199.9 km^2) is characterized by a climate of sub-wet Mediterranean typewith thesoft winters. It is placed in the North prefecture of Larache and in the South of the province Tanger-Assilah, covering the territories of four rural municipalities: El Khaloua, BniGarfatt, Sidi El Arbaa and Yamani Ayacha. Topographically, this site is characterized by a significant altitudinal variation, ranging from 6 m at the outlet to 549 m on the highest peak (Fig.1). Two altitudinal classes [50-100], [100-150] covering 64% of the studied area reflecting its hilly character [14]. Lithologicaly, the central part of this area characterized mainly Cretaceous Marl Habt, OligomioceneSandstones and White Marl Eocene Flint. There are also Soltano-RharbienBenches and TensiftiensTerraces. Numidian and Aquitanian Sandstones and Marl and Limestone-Shale Unit of Tangier are occupying 5% of the studied area,while the sandy downstream region is dominated by Villafranchian's accumulations [15].

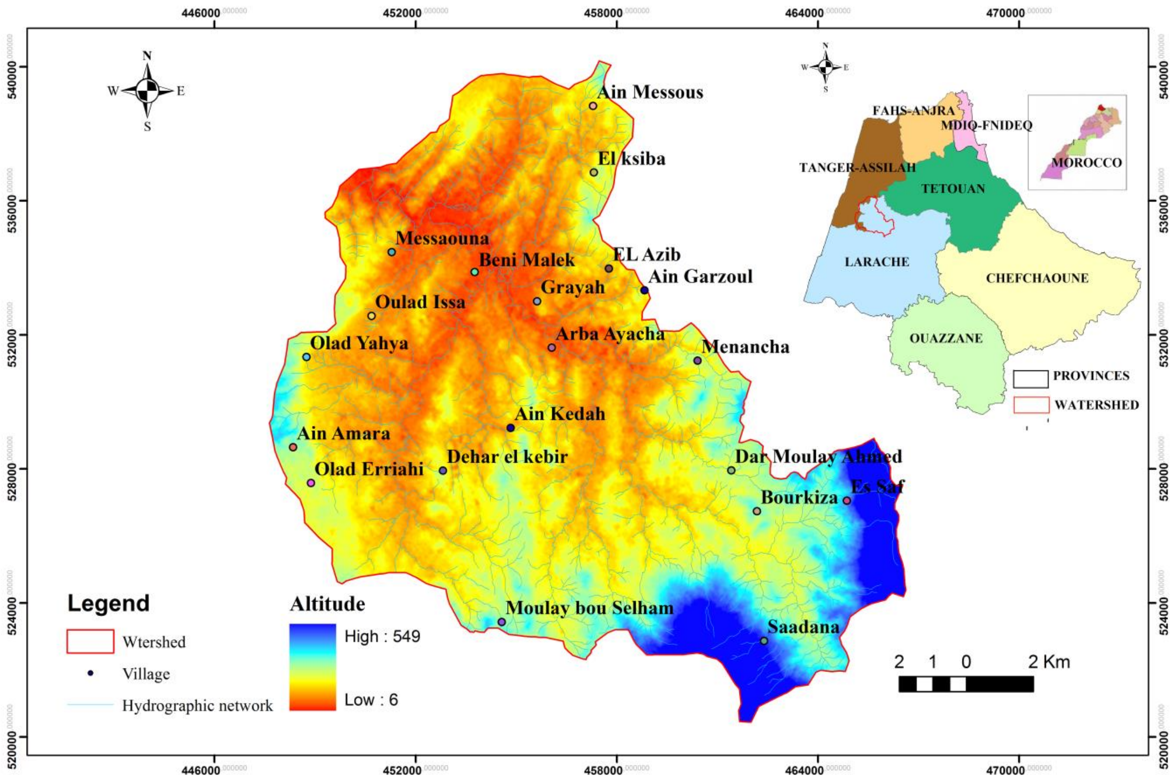

Figure 1: Location and elevation map of Arbaa Ayacha watershed

III. MATERIALS AND METHODS

The IntErO model applied in this study was applied for the first time in Montenegro of the North-eastern MediterraneanRegion [16]. The validation was followed upon a series of the observations and measured sediment yield values from the Potpec accumulation on the river Lim on 1999 and 2011 in PolimljeRegion [13].The author integrated the EPM method in the algorithm of the computer-graphic modelIntErO(Intensity of Erosion and Outflow). The applied methodology rests on two important axes. The first step consists of the collection of the data needed for the database and includes the physico-geographical, topographic, climatic and biological inputs, considered as major factors needed for the assessment of the phenomenon of hydric erosion. The second step is based on the integration of this database in the algorithm of the IntErOmodel.

A. Data resources

- Topographical map used to develop a DTM 25m of resolution consist of the following parameters: River Basin areas (F);Watershed Line Length - Perimeter (O); Area of the Larger part of the River Basin (Fv); Area of the Smaller part of the River Basin (Fm); Natural length of the main watercourse (Lv); Length of the contours (liz); Areas and surfaces between neighboring contours (fiz).
- Geological mapof the Rif with the scale of 1: 500.000 [18]for categorizingwater permeability of the studied River basin.
- Pedological map, prepared by Inypsa [19], used for categorization of the River basin on types of soil products and related types. Furthermore, we used the results of the project of agricultural development in Tangier-Tetouan, supplemented by field research on the preparation of the soil map of the area of Tangier [20].
- Cadaster data for the analyses of the land use, including the remote sensing data for mapping current vegetation cover factor. Landsat 8 satellite images determined the land use in the study area.
- Meteorological data allows the obtaining of the climatic data such as the Torrential Rain Height (**hb**, in mm), the Maximum value of Daily maximum of all months of years, the Mean Annual Air Temperature (**t0**, in °C) and the Mean annual precipitation (**H year**, in mm).

B. Soil loss model application

The parameters taken into account by the IntErOmodel for the calculation of the annual soil loss are summarized in the following equations [21]:

$$W year = T \times Hyear \times \pi \times \sqrt{Z^3} \times F$$

where:

Wyear is the total annual erosion in $m^3 year^{-1}$;
T is the temperature coefficient;
Hyear is the average yearly precipitation in mm;
F is the watershed area in km^2;
Z is the erosion coefficient.

where:

$$Z = Y \times X \times (Ø+\sqrt{I})$$

where:

Y is Soil erodibility coefficient;
X is Soil protection coefficient;
Ø is Erosion development coefficient.

The actual sediment yield was calculated as follows:

$$Gyear = W year \times Ru$$

where:

Gyear is the actual sediment yield in $m^3 year^{-1}$;
Wyear is the total annual erosion in $m^3 year^{-1}$;
Ru is sediment delivery ratio

where:

$$Ru = \frac{(\sqrt{O.D})}{0,2.(L+10)}$$

where:

O is perimeter of the watershed in km;
D is the average difference of elevation of the watershed in km;
L is length of the catchment in km.

IV. RESULTS AND DISCUSSION

1.Physical-geographical characteristics

The study area is located in an attitudinal variation from 6 m.a.s.l. downstream (Hmin) until the highest point of the basin upstream, 549 m.a.s.l. (Hmax). The average river basin altitude, Hsr, is 108.38 m; and the average elevation difference of the river basin, D, is 102.38 m. The DTM allows the realization of the slopes map with the ascendancy of the class (3-12%), which covered 44% of the theritory of the studied area.The values of the maximal slopes are in the Southwest part; the lower's slopes are recorded in the center and towards the Northeast of the studied site. The IntErOmodel calculates successively the average river basin decline, Isr, which equals to 15.19%. The value of 15.19% indicates that in the river basin prevail medium inclined slopes.

2. Climatic characteristics

The climate of the watershed of WadiArbaaAyacha is Mediterranean with Atlantic influence. The average annual air temperature, t0, is 17.85°C, hence the average annual precipitation, Hyear, is 726.67mm. This value is obtained by calculating the monthly and annual averages available in the meteorological station ArbaaAyachafor the period between 1983 and 2016. The volume of the torrent rain,hb, corresponds to the maximum value of each month for the entire period considered (1983-2016) and it is estimated on 60.34 mm. The classification of Strahler [22] allows describing clearly the development of the drainage system of the upstream basin downstream, it shows that it is in order 5, and obtaining permits the total length of the main watercourse with tributaries of I and II class ΣL witch equal 196.48 km.

3. The geological structure and soil characteristics

The lithology and the soil types are two essential factors for the generation of the erosive process. The methodology used in this study allows the exploitation of lithological and soil data for the calculation of the parameter, Y, calculated on 1.5, which is the reciprocal value of the soil resistance to erosion; the numeral equivalents of visible and clearly exposed erosion process, φ, is calculated on 0.17. The degree of the rocks permeability fp, fppand f0 is presented at the Figure 2; the most of the study area is occupied by medium permeable rocks.

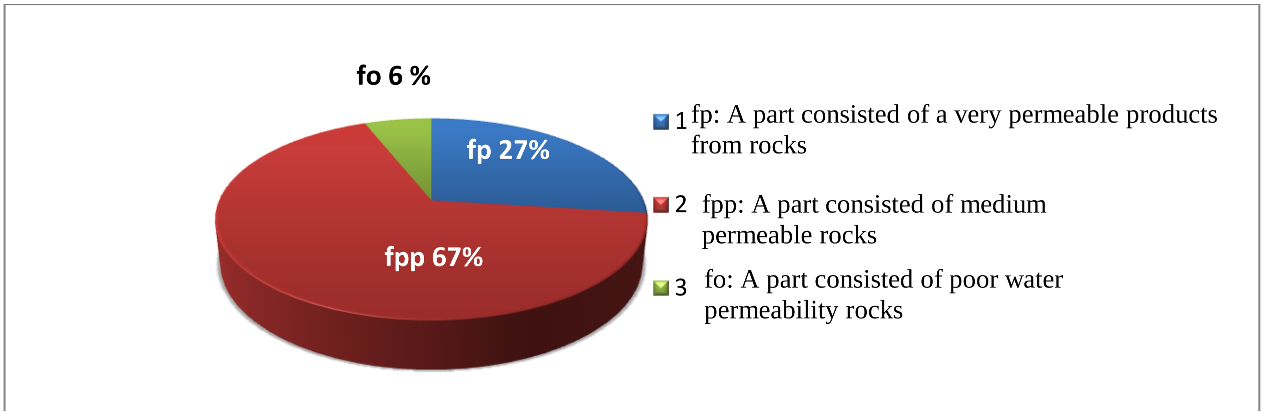

Figure 2:permeability structure of the ArbaaAyacha River watershed

4. Vegetation and land use

The data obtained from the operation of the satellite image Landsat 8 combined with field observations, designed for various types of land use, are processed by the IntErOmodel for characterizingthe runoff. The results shown that the coefficient of the river basin planning of the watershed ArbaaAyacha,Xa,is 0.83. The studied rea is covered by the arrable land, but also with the degraded scrub and bare land (Table 1), while 20% surface is under degraded forest. The dense vegetation that holds the soil and dissipates the energy of rainfall is very limited in the study area. Consequently, grounds are exposed to the erosive risks and soil erosion is quickly degrading the cultivated land.

Table 1:Land use types at the studied River basin of ArbaaAyacha

Plough-lands	74%
Degraded forests	20%
Orchards and vineyards	2%
Bare lands	2%
Mountain pastures	1%
Well-constituted forests	1%

5. Soil erosion and runoff characteristics

The watershed of the river ArbaaAyacha is a favorable environment for development of different forms of water erosion. Indeed, the hydrological behavior of the basin, combined with its lithology, allows the gullies to turn into deep ravines gradually as the water collects downstream. Sheet erosion is predominant while bank undercutting, solifluxion and landslides are too limited (Figure 3).

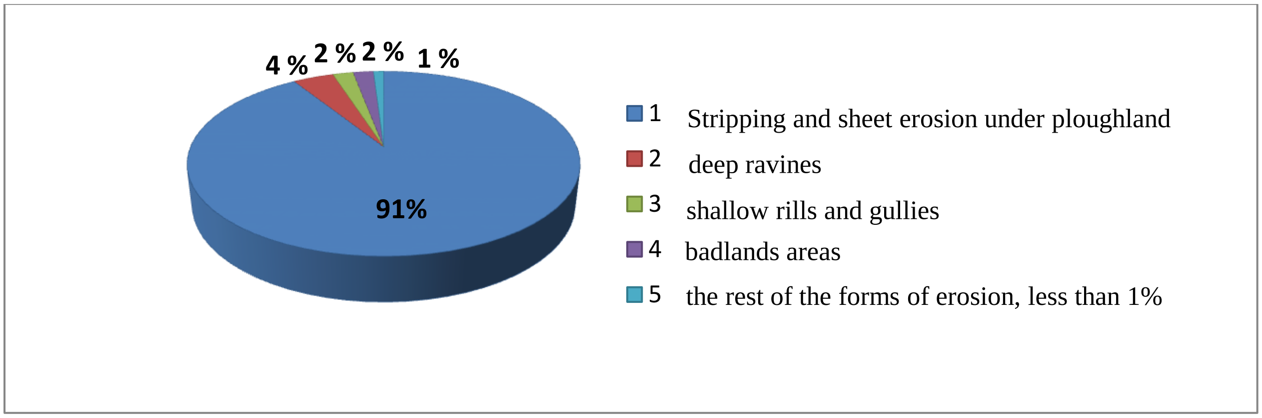

Figure 3: percentage of the forms of erosion in the watershed Arbaa Ayacha.

For calculation of the soil erosion intensity and the maximum outflow, all data listed above are furthermore processed by the IntErOprogram: topographic, climatic, hydrological, biological, geological and soils; and presented at the Table 2 and 3.

Table 2: Part of the IntErO report for the Arbaa Ayacha River Basin - Inputs.

River basin area	**F**	**199.9**	**km²**
The length of the watershed	O	73.8	km
Natural length of the main watercourse	Lv	33.48	km
The shortest distance between the fountainhead and mouth	Lm	19.66	km
The total length of the main watercourse with tributaries of I and II class	ΣL	196.48	km
River basin length measured by a series of parallel lines	Lb	22.7	km
The area of the bigger river basin part	Fv	189.7	km²
The area of the smaller river basin part	Fm	10.2	km²
Altitude of the first contour line	h0	50	m
Equidistance	Δh	50	m
The lowest river basin elevation	Hmin	6	m
The highest river basin elevation	Hmax	549	m
A part of the river basin consisted of a very permeable products from rocks	fp	0.27	
A part of the river basin area consisted of medium permeable rocks	fpp	0.67	
A part of the river basin consisted of poor water permeability rocks	fo	0.06	
A part of the river basin under forests	fš	0.21	
A part of the river basin under grass, meadows, pastures and orchards	ft	0.03	
A part of the river basin under bare land, plough-land and ground without grass vegetation	fg	0.76	
The volume of the torrent rain	hb	60.34	mm
Incidence	Up	100	years
Average annual air temperature	t0	17.85	°C
Average annual precipitation	Hyr	726.67	mm
Types of soil products and related types	Y	1.5	
River basin planning, coefficient of the river basin planning	Xa	0.83	
Numeral equivalents of visible and clearly exposed erosion process	φ	0.17	

Table 3: Part of the IntErO report for the Arbaa Ayacha River Basin - Results.

Coefficient of the river basin form	A	0.43	
Coefficient of the watershed development	m	0.67	
Average river basin width	B	8.81	km
(A)symmetry of the river basin	a	1.80	
Density of the river network of the basin	G	0.98	
Coefficient of the river basin tortuousness	K	1.70	
Average river basin altitude	Hsr	108.38	m
Average elevation difference of the river basin	D	102.38	m
Average river basin decline	Isr	15.19	%
The height of the local erosion base of the river basin	Hleb	543.00	m
Coefficient of the erosion energy of the river basin's relief	Er	45.97	
Coefficient of the region's permeability	S1	0.64	
Coefficient of the vegetation cover	S2	0,91	
Analytical presentation of the water retention in inflow	W	0.7203	m

Energetic potential of water flow during torrent rains	2gDF^½	633.68	m km s
Maximal outflow from the river basin	Qmax	113.72	m³/s
Temperature coefficient of the region	T	1.37	
Coefficient of the river basin erosion	Z	0.694	
Production of erosion material in the river basin	W year	361948	m^3 $year^{-1}$
Coefficient of the deposit retention	Ru	0.126	
Real soil losses per year	G year	45764	m^3 $year^{-1}$
Real soil losses per km^2 per year	G year km^{-2}	229	m^3 km^2 $year^{-1}$

The Result (Table 3) shows that, the coefficient of the river basin form, A, is 0.43 and the coefficient of the watershed development, m, is 0.67; the average river basin width, B, is 8.81 km. The (A)symmetry of the watershed a is equal to 1.83 and this value indicates that there is a reduced possibility for large flood waves to appear.

The Density of the river network of the basin, G, is calculated on 0.98 and this value indicates there is medium density of the hydrographic network. The average river basin decline, I sr, is equal to 15.19. It indicates that in the river basin prevail medium inclined slopes. The maximal outflow from the river basin, Q max, is estimated at 113.72 and the Coefficient of the deposit retention, Ru, equal to 0.126. The Coefficient of the river basin erosion is equal to 0.694 and this value indicates that the river basin belongs to III destruction category. The strength of the erosion process is medium, and according to the erosion type, it is mixed erosion. Finally, the Sediment yield at the catchment outlet, G year, was calculated on 45764.35 m^3 $year^{-1}$, while the specific sediment yield Gyear km^{-2} is 228.94 m^3 km^{-2} $year^{-1}$. This value indicates, according to Gavrilovicclasification, that the River basin belongs to the fifth category region of erosion.

This methodology is in use in various watersheds all over the World. We quote here: Bosnia & Herzegovina, Bulgaria, Brazil, Croatia, Czech Republic, Italy, Montenegro, Macedonia, Serbia and Slovenia [23]. In Montenegro have been successfully used in the Region of Polimlje [24], [25] [26] [27] [28] [29] [30] [32] [33], and In Iran have been successfully used in the regions of Chamgardalan, Kasilian, Kermanshah, Razavi Khorasan [34]; [35]; [36]; [37]; [38]; [39]; [40]; [41]; [42]; [43]; [44] and other regions. The results obtained by our researcher's team we comparedwith the results of some watersheds of Montenegro, as one of the Northeastern Mediterranean Countries.The values at the AyachaArbaa catchment are very similar to the results of the Adriatic watersheds of Montenegro [31], but different if we compare the results with the North Montenegrin River basins of the Black Sea Watershed [24], [25] [26] [27] [28] [29] [30] [31] [32], due to the different characteristics of the two areas, mainly the type of land use, climate, rocks permeability, vegetation and topography.

V. CONCLUSION

The climate, topography, geology, soil types and land use are the main factors that are defining the forms of the erosion process and runoff in the watershed ArbaaAyacha. The Maximal outflow in the river basin, Qmax, was calculated on 113.72 $m^3 s^{-1}$; the strength of the erosion process is medium, and the erosion type is mixed erosion. The calculated specific soil losses (per km^2) were 228.94 m^3 per year. This study demonstrate the efficiency of the IntErOmodel application, as a good and useful tool for the establishment of the databases of watersheds according to the biological, topographic, climatic characteristics.It may help to better understandingof the hydrological behavior of the river basins. It is an efficient and a reliable tool in the modelling of the state of the runoff and soil erosion rate processes and sediment yields.

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