Introduction of inclined open channels for the control of surface runoff of slopes in road structures

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Abstract. The phenomenon of water erosion induced by runoff speeds at the surface of the embankments causes their instability. Particularly in road environments, gullying on the slope's surface due to runoffs causes landslides, which in turn cause considerable damage and consequent disorders to the road network. The aim of this research is to put in place a new technology for superficial water drainage on slope surfaces. Our study has developed a methodology involving the change of the geometric configuration of the water flow, aiming at velocity control of the flows by choosing slanting waterways with small slopes coupled to vertical drains. A modelling of the proposed solution will evaluate its effectiveness as to prevent the erosive factor and to identify other factors that are responsible for slope disorders.

1 Introduction

Erosive phenomena have long been a studies' priority in civil engineering in order to protect constructions (road embankments and roadside slopes in particular) from the effects of water erosion.

Several parameters are known to contribute to the accentuation or mitigation of the erosion phenomenon caused by runoff. A study started at the University of Missouri in 1914 was conducted to measure the amount of soil lost by erosion, leading to the Wischmeier and Smith model established in 1957.

Rainfall in some parts of Morocco, such as the Rabat-Tangier and Fez-Taza highways, has greatly favoured soil displacement on roadside slopes, leading to grain deposit accumulation in rainwater collection ditches at the lower parts of slopes. Potential solutions include geometric land management to divert water by reducing its erosive impact, or planting the embankment to reduce thrusting and runoff. A draining network of concrete arcades is one of the solutions already undertaken on the Rabat-Tangier motorway in order to introduce an artificial factor reducing the erosive phenomenon [1].

The purpose of this study is to present an alternative protection measure, to evaluate its efficiency and to obtain its evolution functions according to the various parameters involved in the RUSLE equation. The solution will then be evaluated to determine reduction rates of eroded quantities versus a reference slope using the RUSLE model parameters [2].

2 Presentation of study zone

The area concerned by the first part of this study is located in the Tangier-Assilah province, located in the Tangérois watershed located north-west of Morocco. It is bound on the north by the Strait of Gibraltar, on the west by the Atlantic Ocean, on the south by the Lower Loukoss watershed and the province of Larache, and on the east by the Côtiers Méditerranéens watershed and the Province of Tétouan. The province's area is 1195 km^2.

Fig. 1. Location of the Tangiers Province and the Tangérois watershed.

Outside the coastal plains, areas with steep or strongly undulating geomorphology cover more than 80% of the region's territory. The Tangérois presents an alternation of valleys mainly covered with quaternary alluvium and marly sandstone hills (figure 2).

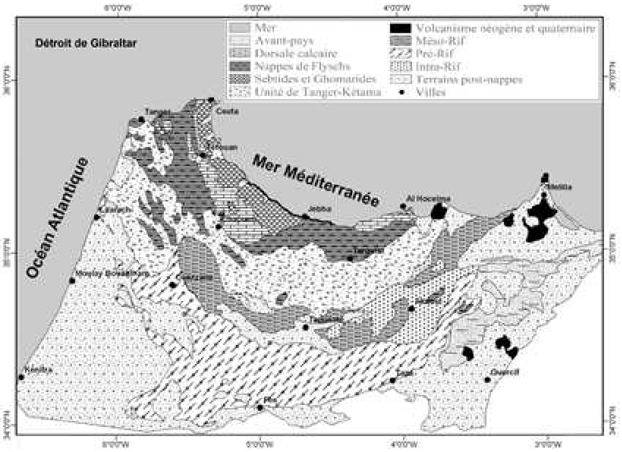

Fig. 2. Geological mapping of the Rif's chain (Rampnoux & al., 1979).

The Tangérois climate is subhumid. The region has an average rainfall of 800 millimeters per year. Eastern winds are dominant in the region. Temperatures generally range from 30°C to 40°C, with few exceptions. East or west winds are common almost every day, and average 7 to 20 km/h.

The main Oueds crossing the region are:
- Descending into the Atlantic Ocean: Hachef, Boukhalf, Bougadou and Mharhar;
- Descending towards the Straits of Gibraltar: Lihoud, Souani, Moghogha and Mellaleh.

The Tanger-Tétouan region benefits from a highway infrastructure composed of these main roads: (1) The A1 linking Rabat to Tangier and the latter to Tanger Med Port, and (2) the A6 linking Tétouan to Fnideq. The highly rugged terrain of the region favors large amounts of soil cuttings, but also the development of the runoff erosion phenomenon, which is a great inconvenience for roadside slopes. Said phenomenon has negative impacts on other aspects such as water quality in retention structures [3].

Other catalytic factors add to the relief: (1) abundant rainfall in the region, (2) dominant marl substratum, (3) degraded natural vegetation, and (4) land misuse.

In addition to water erosion, there is also strong wind erosion, but such phenomena remain localized: we note the formation of dunes on coastal sands; there is significant wind erosion east of Assilah in cultivated sandy soils as well.

3 The Revised Universal Soil Loss Equation

3.1 The RUSLE equation

In order to mathematically determine soil loss amounts by runoff erosion, it was first necessary to determine the parameters involved in the phenomenon. (Cook, 1936) has regrouped them in three categories: (1) rainfall conditions, (2) soil nature and parameters and (3) natural or artificial protection measures for the slopes [4].

The U.S.L.E (Universal Soil Loss Equation) model developed by Wischmeier and Smith involves a set of variables influencing water erosion, which belong to aforementioned categories and are regrouped in the following equation [2]:

$$A = RKLSCP \qquad (1)$$

Where:
- A is the amount of soil lost per unit area and time. The R and K units are conventionally selected in order to obtain A in tons per hectare per year;
- R is the rainfall and runoff factor. It is to be completed by a factor taking into account snowmelt runoff or potentially significant artificial water that may induce erosive phenomena;
- K is the soil erodibility factor taking into account composition and nature of the soil subjected to water erosion;
- L is the slope length factor, defined as the ratio of the soil loss of the length of the slope of land to that of a 22.13-meter-long slope under identical conditions;
- S is the slope effect factor, defined as the ratio of soil loss of the slope to that of a 9% slope under identical conditions;
- C is the cover and crop management factor, defined as the ratio of soil loss of an area with specified cover and management to that of an identical area kept fallow;
- P is the factor of conservation measures and anti-erosion support practices, which is the ratio of soil loss with a support practice against erosion to that of the same parcel without an adequate conservation measure.

3.2 Rainfall/runoff factor R

The rainfall and runoff factor should not take into account a single meteorological factor, but include several of them. Indeed, it is necessary to quantitatively evaluate the impact of a raindrop depending on its fall on the slope surface. It can be highlighted as follows: a high intensity rainfall over a short period can lead to a quantitative erosion equivalent to that of a low rainfall but maintained over a longer period or with higher impact velocity. This lead (Wischmeier & al., 1958) to introduce the rainfall energy parameter [5].

The initial soil moisture can also be introduced in a similar illustration: a previously wet soil promotes runoff, and thus increases the erosive factor compared to said soil in its dry state.

The best estimate of the R-factor is based on the EI_{30} method developed by Wischmeier, taking into account rainfall energy E and maximum rainfall intensity over a period of 30 minutes. This computation approach implies that thunderstorms have already been partitioned into intervals (not necessarily of equal duration) in which intensity is almost constant.

Application of the EI_{30} method, according to (Renard & al., 1991) [6], is impossible in most cases due to unavailability of instantaneous rainfall measurements (in the form of pluviographs). This gave rise to several R-factor approximations based on more readily acquired parameters such as daily [7,8], monthly [9,10] or annual rainfall.

The PNUD/FAO MOR 87/002 [11] project has established an R-factor estimation based on available monthly and annual rainfall averages, and is expressed as follows:

$$Log(R) = 1.299 + 1.744\ Log(\Sigma p_i^2/p_{tot}) \quad (2)$$

Where p_i and p_{tot} are monthly and annual rainfall averages respectively, all taken in inches.

3.3 Soil erodibility factor K

The K-factor reflects the soil's susceptibility to rainfall erosion according to its nature. Indeed, two different soils will not lose equal quantities of matter in similar conditions. *K*-factor is the amount of soil lost on a 9% slope and a 22.13-meter-long unitary parcel [2].

Evaluation of this factor, according to the nomogram of Wischmeier [12], is based on three main factors of the studied soil, including its physical and chemical properties: (1) its proportions in silt, clay and very fine sands, (2) its organic matter content and (3) its permeability (figure 3).

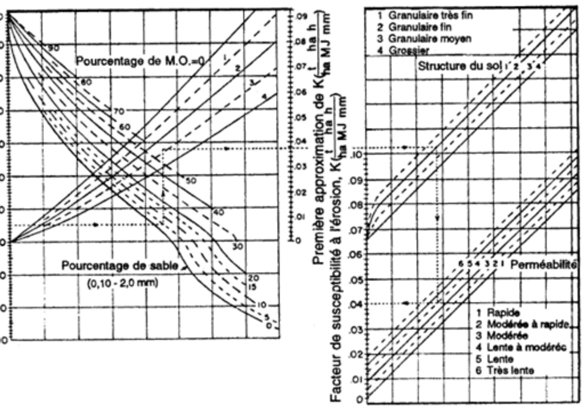

Fig. 3. Wischmeier's nomogram used in determining the *K*-factor [12].

From the nomogram, the following equation is extracted [2]:

$$100K = 2.1M^{1.14}10^{-4}(12-a) + 3.25(b-2) + 2.5(c-3) \quad (3)$$

Where:
- M is the grain size factor, being: M = ($\%_{silt}$ + $\%_{very\ fine\ sands}$) (100 - $\%_{clay}$);
- *a* is the organic matter content expressed in %;
- *b* is the soil's structural class index, which depends on its particle size;
- *c* is the soil's permeability class index, which depends on its textural class.

Table 1. *b*-index used in Wischmeier's nomogram and equation.

Structure type	**Size (mm)**	**Class (b)**
Very fine or structureless	---	1
Fine	< 2	2
Medium	2 to 5	3
Coarse	5 to 10	
Polyhedral, lamellar, prismatic	> 10	4

Table 2. *c*-index used in Wischmeier's nomogram and equation.

Textural class	**Permeability level**	**Class (c)**
Gravel, coarse sands	Fast	1
Silty sands, sandy silts	Moderate to fast	2
Fine sandy silts, silts	Moderate	3
Silts, clayey silts	Slow to moderate	4
Clayey silts, clays	Slow	5
Tight texture	Very slow	6

It should be noted that (Salehi,, 1990) [13] was able to illustrate that the validity of Wischmeier's nomogram was limited to the United States, and that it was affected by soil differences: After studying similar soil types in Canada, it was found that the textural difference between studied soils and those of reference induced differences between the values of *K* obtained using the nomogram and those measured directly on Canadian test plots.

3.4 Topographic factors LS

The two topographic factors *L* and *S* respectively characterize the length and slope of the terrain in their influence on the runoff-eroded quantities. In erosion studies, the disadvantage of considering them separately is eliminated, hence the determination of a single LS factor.

The *L*-factor is based on the ratio between the magnitude λ and the distance of a unit parcel, which equals 22.13m [2]. λ is the distance between the runoff's point of origin and, as the case may be, the point where the slope becomes low enough for solid material deposit, or the point where the water runoff is introduced into a channel purposefully built for drainage (in the case of a drainage network or a built channel).

The *S*-factor represents the influence of slope inclination on the amount of eroded soil. This factor can be determined in case of constant gradient slopes.

The *L*-factor is as follows:

$$L = (\lambda/22.13)^m \quad (4)$$

Where *m* is a variable characterizing the favored mode of erosion in the studied slope (if furrows favor the erosive factor or not). Said magnitude involves a factor β. The exponent *m* is given by the following formula, θ being the slope's angle:

$$M = \beta/(1+\beta) \text{ where } \beta = \sin\theta/[0.0896(3\sin\theta+0.56)] \quad (5)$$

(Wischmeier & Smith, 1978) gave arbitrary values of *m* to be chosen according to slope inclination, without taking into account the effect of erosion mode: (1) 0.5 for slopes greater than 5%, (2) 0.4 for slopes between 3.5% and 4.5%, (3) 0.3 for slopes between 1% and 3%, and (4) 0.2 for slopes less than 1%.

The slope-effect factor S is given by the following undermentioned formula [2]:

$$S = 65.41(\sin\theta)^2 + 4.56\sin\theta + 0.065 \quad (6)$$

Thus, the LS-factor can be given in the formula:

$$LS = (\lambda/22.13)^m [65.41(\sin\theta)^2 + 4.56\sin\theta + 0.065] \quad (7)$$

3.5 Cover and management factor C

C-factor, as defined by (Wischmeier & Smith, 1978), is the ratio of soil loss from a crop area (or any crop management program) to loss of the same fallow area under identical conditions.

In case where the soil has not been cultivated, factor *C* is not taken into account in the RUSLE equation, thus giving eroded amounts equal to *RKLS* in the absence of protective measures. In other words, value of *C* is taken equal to one for fallow land. In case where crops or a management program is put in place, the value of *C* is much lower.

Apart from the values in the USDA Manual N°537 (Wischmeier & Smith, 1978), research on *C* values has remained insufficient. Some comparisons were made between the manual's values and measured values for the Lennoxville area in Canada (Salehi & al., 1991), indicating good comparability for soils outside the United States.

3.6 Support practice and conservation factor P

By definition, the *P*-factor in the revised USLE equation is, according to (Wischmeier & Smith, 1978), the soil loss ratio of a parcel with conservation measures to an identical parcel without said measures, cultivated in the slope's direction.

Existing anti-erosion support practices include contour cultivation, contour ridging, stripcropping, terracing [2], and natural or fabricated mulching.

Anti-erosion techniques break down into two families: biological and mechanical. In arid zones, mechanical techniques take over and are more developed and recommended because of the difficulty of adopting biological methods, although a vegetation cover multiplies the support practice's effectiveness.

4 Describing the designed method

The introduction of a new superficial drainage method mainly affects the *P*-factor value of the RUSLE equation. (Shin, 1999) gave *P*-factor values for different agricultural practices and for different slope values in table 3:

Table 3. *P*-factor values for different agricultural practices.

	Contouring	Stripcropping	Terracing
< 7.0	0.55	0.27	0.10
7.0 – 11.3	0.60	0.30	0.12
11.3 – 17.6	0.80	0.40	0.16
17.6 – 26.8	0.90	0.45	0.18
> 26.8	1.0	0.50	0.20

The purpose of surface runoff drainage is to collect runoff water and convey it to a collection point through a defined flow network, which will also reduce the LS value according to the definition of (Wischmeier \& Smith, 1978). Reducing runoff's travel distance on the soil surface will also contribute to reducing furrow-induced erosion, a phenomenon likely to occur in freshly built slopes.

The suggested solution is about realizing a runoff drainage network composed of: (1) concrete channels quasi-perpendicular to the runoff's direction with an inclination varying between a 10 and a 20-degree angle, along with (2) equidistant vertical water descents linking aforementioned channels. Points of intersection of channels and descents will be out of phase in order to induce a flow discontinuity in vertical elements, thus limiting flow velocities in channels and risk of degradation of concrete matter constituting the solution's elements (figure 4).

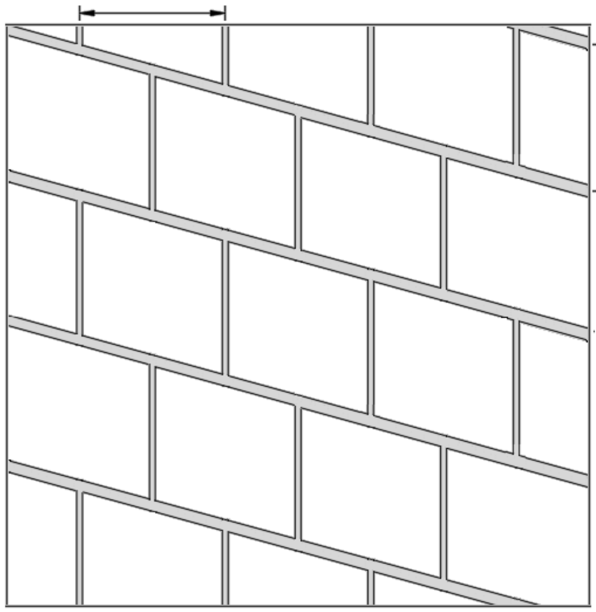

Fig. 4. Scheme of the suggested drainage solution on a one-hectare square experimental parcel (Channel inclination is 15 degrees and spacing between channels and descents equal to 25 meters).

Disposition of a runoff diversion ditch perpendicular to the slope renders our approach similar to contour ridging. The main objective of inclined channels, as for soil ridges, is to reduce the runoff's energy by nullifying runoff velocity and facilitating rainwater runoff's catchment. Choice of concrete for inclined channels and descents has several advantages: (1) canceling water infiltration, avoiding saturation of the upper part of the ground, (2) reducing landslide risk of superficial layers, (3) avoiding ditches' clogging and (4) offering the possibility of exploiting collected water in other potential uses.

The geometric similarity of the inclined channels and ridges allows us to estimate an anti-erosion factor close to that considered for the ridging method. The actual effectiveness of the method can only be evaluated by an experimental study quantifying eroded soils in the presence of the designed method compared to a similar quantitative on reference plot without anti-erosion measures. A value of 0.5 would be appropriate, since contour ridging is known to reduce by half the eroded quantities in crops perpendicular to slope direction; and for slopes exceeding 25% (which is the major case of road embankments), the presence or absence of vegetation does not have a significant contribution (value of *P* between 0.9 and 1 without ridging (Wischmeier & Smith, 1978)).

5 Results and discussions

5.1 Rainfall runoff factor

Rainfall data for calculation of *R* are obtained from the rainfall pluviogram shown in figure 5, showing rainfall distribution over a typical year as well as temperature variations during the same year. For such a year, the average annual rainfall is around 700 millimeters. The station is located at coordinates 35°43'43' 'north, 5°55'01" west.

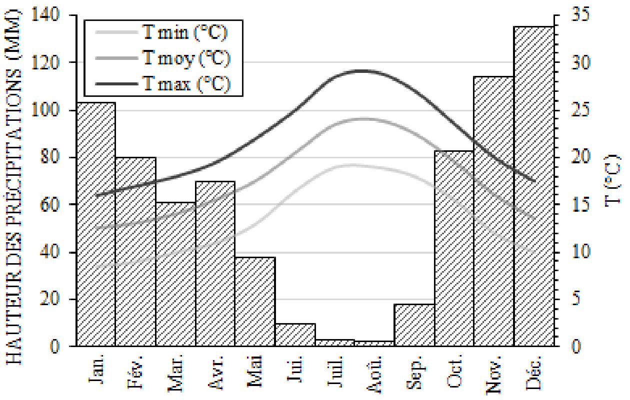

Fig. 5. Rainfall in millimeters and temperatures per month in the Tangier region (INRA, 2007).

In this application, we will use the Rango & Arnoldus model [11] involving monthly and annual rainfall averages instead of rainfall energy. The value obtained for the rainfall factor in our case study is 186.34 $MJ.mm.ha^{-1}.h^{-1}.year^{-1}$.

Multiple rainfall samples from several years (including dry and wet ones) will allow a better estimate of the R-factor. (Ouallali & al., 2016) evaluated the erosivity factor in the Oued Arbaa Ayacha watershed at the frontier of the communes of Larache and Tangier-Assilah between 100 and 125 $MJ.mm.ha^{-1}.h^{-1}.year^{-1}$ [14]. (Khali Issa & al., 2016) estimated the factor in the Kalaya watershed between 94.7 and 96.6 $MJ.mm.ha^{-1}.h^{-1}.year^{-1}$ [15]. (Modeste & al., 2016) studied the R-factor on the Ourika watershed and found values between 55 and 100.5 $MJ.mm.ha^{-1}.h^{-1}.year^{-1}$ [16]. (Yjjou & al., 2014) also estimated the R-factor for the upper Oum Er-Rbia watershed between 70 and 119 $MJ.mm.ha^{-1}.h^{-1}.year^{-1}$over most of the watershed's area [17].

5.2 Soil erodibility factor

Soils concerned by the study were taken from sites near the commune of Gzenaya in the Tanger-Assilah province. The green clays taken were kept in their natural state as best as possible, and a paraffin shell served as hygrometric insulation allowing minimal alteration and accidental water content variation [18].

Geotechnical study of the collected samples underlines the highly plastic nature of soils north of the country and the preponderance of clayey particles. A percentage of fine sands and silts of 49% and a clay particle content estimated at 35% were found. According to the USCS classification, this soil is classified as CH (inorganic clays with high plasticity).

(Edahbi & al., 2014), in their study of soils in the Loukkos region south of the study area, calculated the organic matter content of Dehs (with particle size distribution close to the studied soil) using organic carbon content by multiplying it by the universal coefficient of 1.724, resulting in a percentage of organic matter equal to 1.01% [19].

We will use a value of 1% for this first part of our study. Calculating the value of *K* gives a value of 0.245 $t.h.MJ^{-1}.mm^{-1}$. (Khali Issa & al., 2016) found values of up to 0.724 $t.h.MJ^{-1}.mm^{-1}$ for the most erodible soils in the Kalaya watershed [15]. (Modeste & al., 2016) find *K* values between 0.15 and 0.69 $t.h.MJ^{-1}.mm^{-1}$ for the Ourika region [16]. (Markhi & al., 2015) find that this value varies from 0.23 to 0.85 $t.h.MJ^{-1}.mm^{-1}$ for the N'Fis watershed [20].

5.3 Cover factor

In our study, we must consider the slope's initial state at the very commissioning of the road project including it. In general, freshly constructed embankments are not vegetated, which will lead us to a cover factor *C* equal to 1 [2].

Planting of the protected slope is one of the strong recommendations for improving this solution. As local planting and use of local plants is common practice in the country, it is recommended in our case study to reduce runoff quantities and kinetic energy of the rains favoring the erosive water factor.

5.4 Support practice factor

The conservation method factor *P* is taken as 0.5 in our case. A comparison of two test plots will allow us to have a value specific to the solution, but will nonetheless be inferior to than 0.5 since this value considers a very unfavorable state of the solution, making it almost similar to the agricultural ridging solution.

5.5 Topographic factors

As part of this study, we took a simplified square study plot of one hectare to show the effect of changing the geometrical parameters of our solution (in particular, the spacing between the inclined channels and the vertical descents) on the gain in eroded quantities. Calculations were made on channels inclined by a 15-degree angle and spacing values of 50 m, 33 m, 25 m, 20 m, and a tight mesh of 10 m of spacing to illustrate the usefulness of channels' number. The aforementioned spacings correspond to a number of inclined channels equal to 2, 3, 4, 5 and 10 channels respectively.

In the case of clay or clayey soils, a suitable terrain slope would be between 1V:3H and 1V:1.5H, equivalent to slope percentages between 33% and 67%. Both layouts and lower slopes (10% and 25% slope) were studied in order to evaluate eroded amounts' reduction from a steep slope to a weaker one. A comparison between cleared quantities for two slope percentages and gain in the form of non-eroded soils was performed.

5.6 Eroded soil amounts

Our simulations' results include area reductions provided by the designed drainage method, eroded soil quantities per year on the one-hectare square test plot considered and a relative comparison between different geometric parameter changes of the method. They are summarized in the following table:

Table 4. Erodible soil surface reduction and *A*-values for a square one hectare parcel.

	50 m	**33 m**	**25 m**	**20 m**	**10 m**
S_b : covered area by concrete channels and descents					
m^2/ha	177.03	267.29	375.06	467.82	945.14
%	1.77	2.67	3.75	4.68	9.45
A : eroded amounts in tons per year					
10%	39.89	31.87	27.30	24.08	15.98
25%	189.62	144.04	119.27	102.41	62.45
33%	305.97	229.77	188.81	161.13	96.40
67%	921.52	677.47	548.86	463.07	267.39

It is found that with the introduction of two inclined channels and appropriate descents connecting them, and maintaining the approximation of *P* to the 0.5 value of the homologous approach of contour ridging in the protections of agricultural parcels, cutting the runoff path allowed the reduction of eroded soil amounts to percentages between 30% and 34.5% of that with no runoff drainage solution on the four simulated slopes (figure 6).

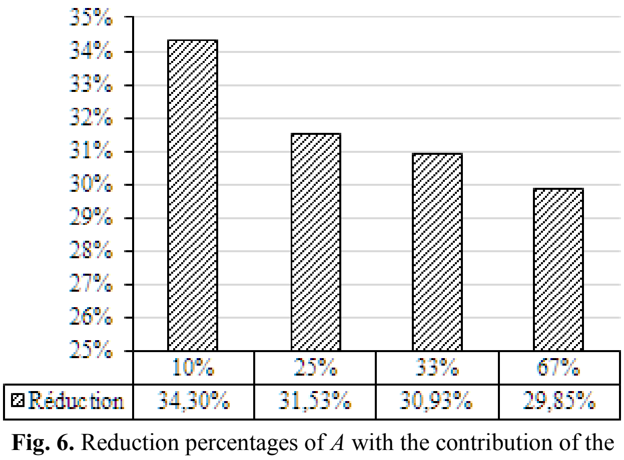

Fig. 6. Reduction percentages of *A* with the contribution of the inclined two-channel drainage solution versus embankment slopes.

Eroded quantities are greatly reduced by reducing slope or multiplying water interceptors. (Chehlafi & al., 2014) draw an identical conclusion for the solution in concrete arcades arranged by the Autoroutes Du Maroc on the A1 highway linking Rabat to Tanger [1].

A considerable reduction (between 35.2% and 38%) in the amount of land lost by water erosion is possible by moving from an inclination of 33% to 25%. this amounts to a larger quantity of cuttings during the realization of the slope, but remains limited to 21% of additional cut. Higher reductions occur when lowering slope value from 25% to 10% slope (between 74% and 79%), but a slope of 10% remains extremely low, prompting excessive excavation.

Going from a number of inclined channels to a greater number also reduces eroded quantities: with a passage from two channels to three, the value of A is reduced to 75% of the quantity (evaluation carried out on 33% and 25% slopes). Higher reductions are possible and it is found that these are almost identical throughout the slopes taken, and in particular between 25% and 33%, favoring again the choice of the lower slope.

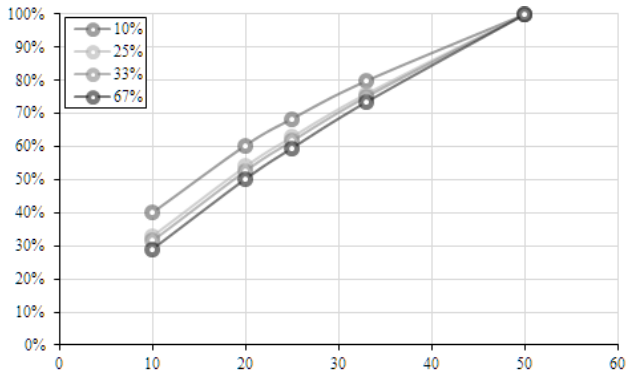

Fig. 7. Reduction percentages of *A* versus channel spacing by slope inclination (relative to two-channel layout).

5.7 Dimensioning of collection ditches on embankment foot

Dimensioning of the collector ditch should allow the flow and transport of solid particles without any deposited volume affecting said transport. Our test plot is characterized by a thrust with an average density on the samples of 1.74 t/m^3 in the Gzenaya region [18].

It can be considered that the flow does not allow the transport of solid grains beyond a ditch filling greater than half of its section. This will allow us to apply the formula:

$$A_{max} = 0.5\rho_h L_{ditch} S_{ditch} \quad (8)$$

For ditch sections, we referred to the STRADAL catalog for opencast hydraulic ditches. The following ditch areas will be studied: 0.5 m^2, 0.8 m^2, 1.125 m^2 and 1.301 m^2. The maximum section of the supplier will also be taken into account, but it should be noted that its own weight per meter (more than one ton per meter of concrete ditch) and its installation would require heavy machinery if not cast on site.

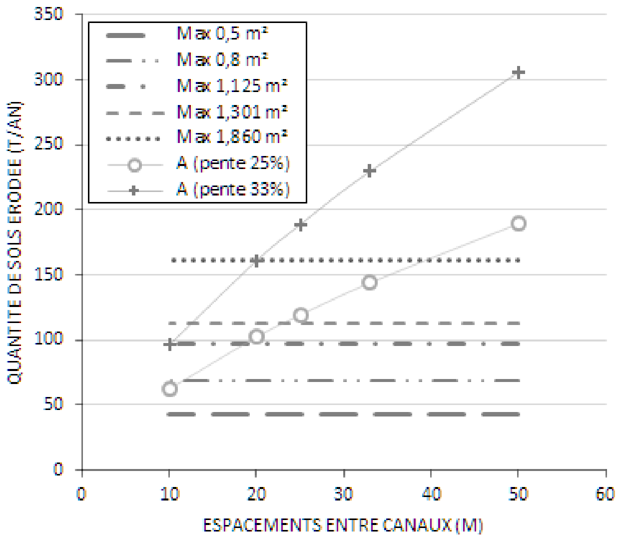

Fig. 8. Tolerance of ditches in relation to eroded soil amounts at 25% and 33% inclination (Eroded quantities versus channel spacing).

According to the graph in figure 8, it is necessary to consider higher section areas for the collecting ditches to be realized. The design of a particular trapezoidal section would be the best approach: a section that can be reconstituted from concrete slabs easily moved on site and assembled to form the ditch while having adjustable geometric configuration depending on the selected area.

5.8 Minimum spacing between inclined channels

In order to allow a direct choice of the collection ditch area and the appropriate spacing for the designed solution, a numerical solution based on the factors of the RUSLE equation has been established.

In this sense, the maximum capacity supported by a main collection ditch at the foot of the embankment was taken equal to half of its section and the study was conducted on the same square 1 ha test section as previously defined.

Minimum spacing necessary for the channels to allow them to ensure a correct drainage according to the fixed collection ditch area was evaluated on 7 different soils: two samples of the clays of the Tangier region including Gzenaya [18], Gharb tirs [21], Loukoss tirs [19], Doukkala tirs [22], and two soils collected from the Lemhaya area near Fès [23], as well as the Ifrane region.

The established formula for this study is as follows:

$$e_{min} = \alpha(0.01R)^{\beta} K^{\gamma} S_{ditch}^{\lambda} \quad (9)$$

Where:
- $\alpha = 0.136(\sin\theta)^{-2.271}$
- $\beta = -1.286(\sin\theta)^{-0.133}$
- $\gamma = -2.0734(\sin\theta)^2 + 2.272\sin\theta - 2.1418$
- $\lambda = 1.2078(\sin\theta)^2 - 1.5027\sin\theta + 1.8554$

In the majority of the simulations carried out, an error margin of around 5% between values of A obtained with spacings calculated by this formula and the maximum capacity supported by the embankment's collection ditch is ascertained, confirming the validity of this approach for direct calculation of the spacings adapted to each chosen ditch.

6 Conclusions

The contribution of the surface inclined channels drainage solution reduced the amount of soil eroded on the studied test plot to nearly 35%.

A change from 33% to 25% was found to have a considerable effect on the reduction of L and S factors, hence the lesser eroded soil quantity. A reduction in channel and descent spacing, considered equidistant in our study, also contributes to the reduction of the runoff path, lowering the A-values with a trend independent of slope value.

The evaluation of the spacings required for a set of ditch areas at the collection ditches made it possible to predict a layout of the drainage network by directly exploiting the same parameters of the RUSLE equation, thus facilitating studies to the optimization of the channel sections and the arrangement of the vertical descents according to the desired in-channel velocity adjustments.

A more accurate estimate of the value of the anti-erosion measurement factor will give us greater precision in our simulations, and will confirm this solution as suitable for the surface drainage of highly erodible road embankments. The participation of a revegetation of erodible surfaces will have a dual role: (1) improving the efficiency of the solution by reducing the value of C (and of A as a consequence), and (2) a better integration of the method in the landscape and the environment.

The study of this solution by varying the dimensions and the inclinations of the channels will be able to orient the solution towards an optimization of the spacings and dimensions of the channels and descents according to the type of soil. The flexibility of this solution will also allow its implementation on slopes with more than one type of soil.

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