Cadernos de Geografia nº 40 - 2019
Coimbra, FLUC - pp. 53-66

Soil degradation in Central Rif mountains area in northern Morocco: aspects of losses and failure of development programs

Degradação do solo na área montanhosa do Rif Central, no norte de Marrocos: perdas e falhanços dos programas de desenvolvimento

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Abstract

In the Rif region in northern Morocco, the degradation of the environment exposes the soil to aggressive erosion agents, especially in the Mediterranean climate in which the evacuation of 2000 tons of soil per km^2 per year is a basic average. In these difficult environments is necessary to manage the resource effectively by anticipating the situations of dry and wet years. Several development programs have been carried out in the Rif zone since the 1960s and the problem persists, especially with the arrival of the new agriculture of Cannabis (Drug) in 1995 in the southern part of the study area which is characterized by its precarious environmental balance. This paper aims to examine the aspects of soil degradation and analyze the failure factors of the management programs and projects that have been conducted by several national and international stakeholders including the EU and UN.

Keywords: soil degradation, land management, natural resources, Rif, Morocco.

Resumo

Na região do Rif, no norte de Marrocos, o clima mediterrâneo e a degradação do ambiente expõem o solo a agentes erosivos intensos, com a mobilização média, em cada ano e por km2, de 2000 toneladas de material inerte. Nestas condições adversas, impõe-se uma correta gestão dos recursos, antecipando os ciclos mais secos e mais húmidos. Neste espaço geográfico, desde os anos (19)60, aplicaram-se diferentes programas de desenvolvimento. No entanto, o problema persiste e agudizou-se mesmo a partir de 1995, com o cultivo de Cannabis (Droga) que se expandiu no setor sul desta região especialmente vulnerável. Este artigo pretende analisar o processo de degradação do solo e discutir o falhanço dos programas e projetos de gestão implantados por diferentes atores nacionais e internacionais, incluindo a União Europeia e as Nações Unidas.

Palavras-chave: degradação do solo, gestão ambiental, recursos naturais, Rif, Marrocos.

1. Introduction

The different aspects of soil degradation in the Rif region resulting from inappropriate agricultural practices and from an intensification of uncontrolled Cannabis agricultural. Mechanization, sometimes unsuited to soil conditions, is responsible for problems of settlement of wet soils or, conversely, for the disintegration of land in the semi-arid regions of the Prerif area, which makes them suitable for erosion. Degradation of soil in the study area decreased fertility, increased water and mass erosion and or in

https://dx.doi.org/10.14195/0871-1623_40_4

alluvial plains and reduced soil water retention capacity.

Intervention strategies have focused on land degradation and have often failed to address the fundamental problems of the marginalized Rif region, such as the problem of the enslavement of entire massifs or the devaluation of the agricultural economy. However, it seems that economic underdevelopment and environmental degradation are linked; Indeed, it is difficult to envisage effective resource protection in the absence of innovative policy, based on the desire to boost the economy of the Rif Mountains and the development of new and sustainable resources.

The concern for the development of the Rif mountains area, therefore, consists of the balanced management of resources and their development for the creation of reproductive factors, capable of generating sustainable development, likely to retain the population and enhance the labor absorption capacity. It is also a concern to curb the degradation processes that can lead to the desertification of the Rif territory and consequently to absorb the flow of illegal migration to Europe through the Mediterranean Sea and southern Spain.

For this purpose, conceding local opinion is necessary; it is about creating a space for dialogue and consultation with target groups and not imposing a technocratic vision. In this perspective, we find the other connection of the dimension of natural resources and that of development, only effective progress and term of economic, human and social development, in an integrated way on several fronts, can guarantee success in the protection of heritage soils and the balance of territories.

2. Study area

The study area located in Northern Morocco, bounded to the North by the Mediterranean Sea, to the south by the Prerif zone, in the Western part is limited by the Western Rif and to the east by the Eastern Rif (Figure 1).

This division was designed by several researchers based on different criteria and especially the geological structure (Asebriy, Luca, Bourgois, & Chotin, 1987; Maurer, 1968).

The Central Rif is undoubtedly the region most affected by various types of degradation. These

Figure 1
Localization of the study area in Central Rif Mountains northern Morocco.

phenomena, which have a considerable impact on the natural environment, are also the major and permanent threat to the environment and society.

3. Settings and Data

The Central Rif area is very vulnerable to the degradation of natural environments, as it is characterized by a regression of its protective vegetative cover combined with steep slopes, the predominance of friable lithological formations (marl, marl-limestone, and shale) and abundant rainfall.

The Rif mountain chain constituting the southern branch of the Gibraltar arch borders of the Alboran basin (SW of the Western Mediterranean). The current evolution is complex and results from multiple orogenic processes (burial, exhumation and rifting), in relation to the convergence between the Eurasian and African lithospheric plates (Andrieux, 1971).

3.1. Geological factors

The study area of Central Rif mountain is divided into three big geological categories (Asebriy et al., 1987; Maurer, 1968). In the Northern part, we find the Intrarif zone in direct contact with the flysch zone limited by the Mediterranean Sea, in the southern part there is the Prerif area and in the middle part the Mesorif domain (Figure 2).

The Intrarif zone consists of three unities, Ketama unit which appears in the Central Rif (Andrieux, 1971), affected by two schistosity phases and two metamorphism phases. The first phase is of upper Oligocene and lower Miocene, and the second of Upper Miocene (Frizon de Lamotte, Andrieux, & Guézou, 1991). Tangier unit is a little deformed, it is considered as the cover of the Ketama unit, with a stratigraphic series from the Cenomanian to the inferior Miocene. However, it is symbolized by clay marls of the Upper Cretaceous. Loukkos unit is a zone of tectonic scales, which is flushed in the Western Front of the Tangier unit. These facies are of age ranging from the Albo-Aptian to the Eocene (Benyaich, 1991; Lespinasse, 1975).

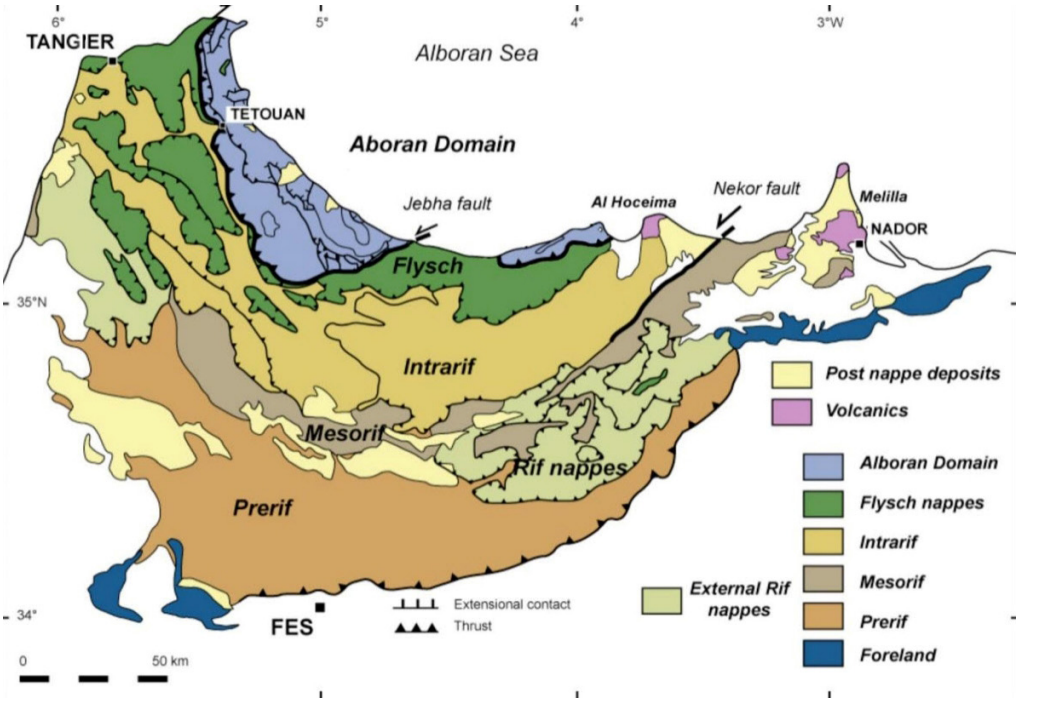

Figure 2
Geological structure of Central Rif mountain.
Source: Extracted and adapted from Suter & Mattauer, 1964.

Mesorif domain is also named window areas and is characterized by a set of antiforms, whose hearts consist of formations from the lower to middle Miocene overlapped by allochtones and pleated Mesozoic layers (Durand-Delga et al., 1960). This current structure has been interpreted as:

- The African Jurassic-Cretaceous passive margin that had undergone a tectonic inversion and would have formed the Miocene Mesorif structure zone (Benzaggagh et al., 2014).
- A block of the Tell margin -Algeria) that would have displaced about 250 km westward to the Upper Oligocene-Miocene due to a major movement of transforming fault and oblique to the paleomark, named Oran-Mesorif Strike-Slip Fault (Benzaggagh et al., 2014).

Prerif domain is dominated by Jurassic and Cretaceous formations, the same as Mesorif domain, are represented by three different series (Wildi, 1981):

- A thick formation of flysch.
- A limestone series, forming the Sofs line.
- An alternating series with dominant of marl formations.

These lithological materials are very friable and have a very high sensitivity to climatic variations.

3.2. Climatic aggressiveness: Factor of degradation

The rainfall annual average of the study area varies between 600 mm/year and 1500 mm/year. The variability of the annual rainfall in the study area reached more than 100% between the two stations localized in two extremes borders of the study zone (Figures 3 and 4).

The number of dry years, with rainfall less than 400 mm, has increased since the early 1980s. The dry-year frequency has increased fivefold from a dry year to a normal 15 years in the 30s, 40s, 50s, 60 and 70, to a dry year out of 3 during the last three decades (Jlibene, 2011) especially in semi-arid areas as the case of the southern part of our area is studied in the Prerif.

Between these values, there are events that give very large amounts of water in a few days, or even in just a few hours with very high instantaneous intensities. Their occurrence is related to disturbances of the N-NW sector or only to thunderstorms of thermo-convective origin. They intervene directly in the mechanisms of erosion and flooding and thus act on the effect of the torrentiality of the waters in the rivers. Their repercussions on the Rif are sometimes catastrophic: they can cause human tragedies and very important economic damages.

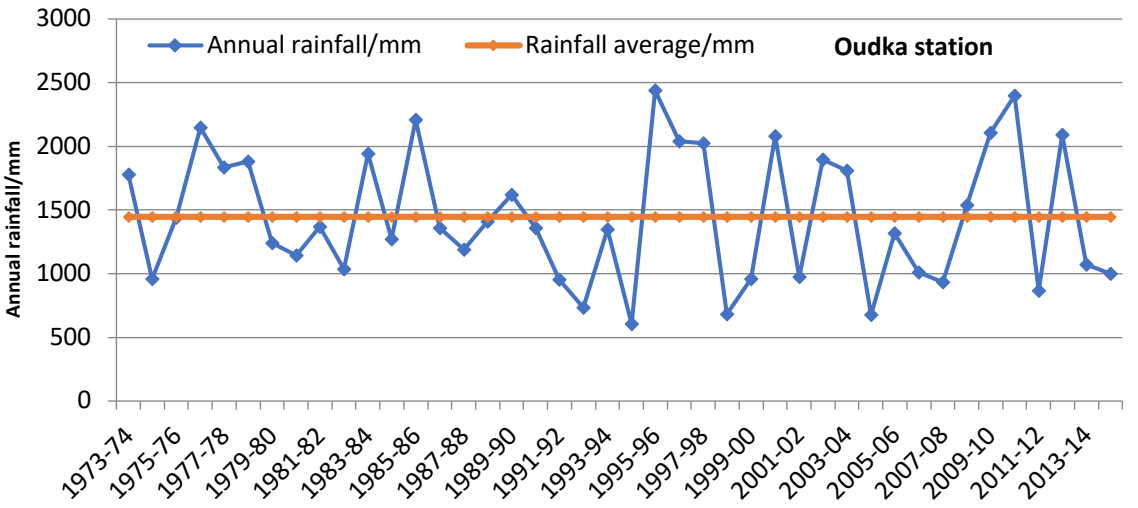

Figure 3
Variability of the annual rainfall at Jebel Oudka climatic station in the North of the study area.
Source: ABHS, 2016.

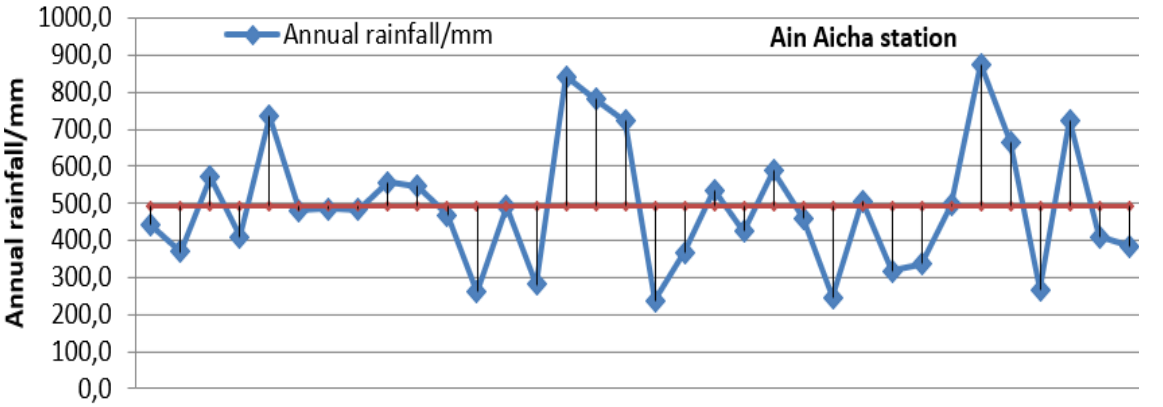

Figure 4
Variability of the annual rainfall at Ain Aïcha climatic station in the south of the study area.
Source: ABHS, 2016.

4. Degradation of soil resources aspects

The Rif mountain is a place of imbalances. The first imbalance between natural resources and anthropogenic pressure, a second economic imbalance, manifested by low production and incomes, and finally a spatial imbalance in comparison with the Atlantic or Mediterranean plains, A natural imbalance which further aggravates the precarious situation of the physical environment.

As the soil is the surface part of the earth is likely to be cultivated due to its physical and chemical properties, clearing activities focus on this horizon. The first major repercussion of different forms of deforestation is the soil degradation, which is a natural phenomenon inherent in its biological, chemical, physical and hydrological properties that energize our planet. Soil degradation occurs when there is a decline in its productive or functional capacity (Pautrot, 2012).

The Rif Central mountain is individualized by its orographic and rainfall characteristics; These are environments where altitude raises rainfall in relation to the surrounding areas with a series of handicaps (very limited agricultural land, difficulties in transport, the emergence of cannabis agriculture). This region is also, an old demographic home where settlement is very old. Human densities are still impressive. They reach a record of more than 100 h/km^2 with a density that exceeds 300 h/km^2 in some rural communities. The human influence and agrarian conquests are spectacular. Most slopes are totally bare and cultivated.

Considering the young and unstable character of the Rif Central reliefs, the fragility of the natural environment and its high susceptibility to degradation factors, The current dynamics through various forms of soil degradation, are greatly amplified by human interventions (Beaudet, Martin, & Maurer, 1964).

4.1. The gully

The Central Rif Mountain is characterized by the predominance of friable lithological formations such as marls, marl-limestones, and schists. The soils formed on these rocks were until the 1950s protected by relatively dense natural vegetation (Sadiki, Bouhlassa, Auajjar, Faleh, & Macaire, 2004). The intensity of erosive manifestations in this environment causes terrible damage and, consequently, poses social and environmental problems by its associated effects.

4.2. Sheet erosion

This is the initial stage of soil degradation. This sheet erosion leads to degradation of the soil over its entire surface, a form of diffuse erosion is not very visible from year to year. Sheet erosion is, therefore, the presence of light-colored beaches at the most pickled locations. The process of surface erosion created by clearing is the destruction of the aggregates by the impact of raindrops. It is only after the formation of the puddles and the overflow of infiltrated water from one puddle to the other that the surface runoff occurs.

Figure 5
Soil stripping due to the sheet erosion in Prerif zone. The situation of September 2019.

Figure 6
Preparation of materials for erosion on the rural tracks permanently frequented by the herds.

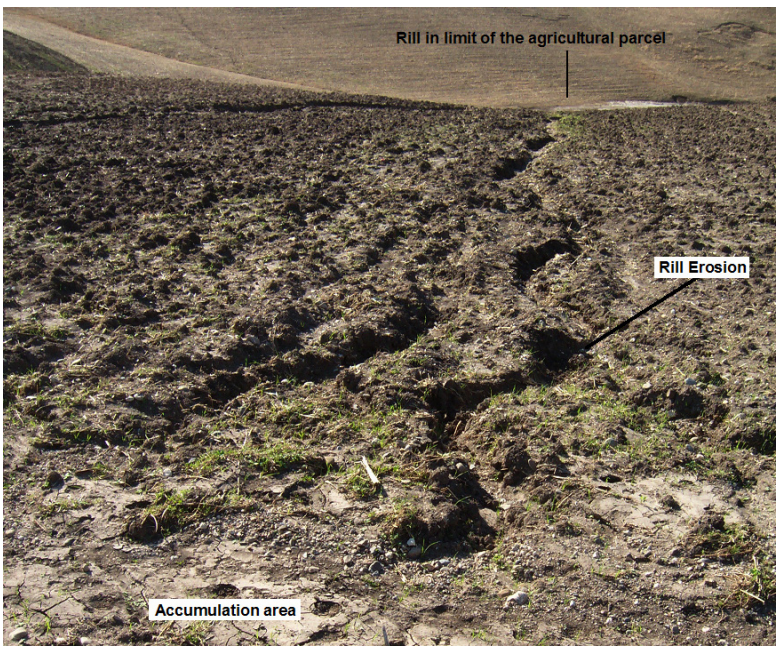

Figure 7
Series of small channels on marl slopes carved by running water in Prerif area. The situation of October 2014.

Water erosion can decrease the fertility of the soil or even make it infertile; this situation is aggravated by the rural tracks permanently frequented by the herds, at the end of the rural villages (Doaurs), are forms of extreme degradation with marl rocks (Figures 5 and 6).

Figure 8
Deeply incised gully formed on the steep slope in Leben Watershed in Prerif area. The situation of September 2015.

4.3. Rill erosion

The area of the central Prerif, on bare or covered areas waterproofed by marl formations, even a small amount of rain triggers a significant runoff can concentrate in the bottom and acquire locally critical values of flow, resulting in the formation of rill-erosion (Le Bissonnais et al., 1996). They play a major role in the incidence of damage, and occur either at the limits or inside of the agricultural parcel (Figure 7).

In the case of the Prerif area, the cultivation of cereals, usually in October, on plowed land increases the porosity of the soil and, consequently, its infiltration capacity. It allows opening the surface of the soil, to break the crusts and to reinforce the roughness forming the small elementary gullies.

4.4. Gully erosion

The Mediterranean climate is renowned for its erosive showers. This condition reinforced by the fragility section areas, according to the degree of slope, the Prerif zone showed that it has a significant influence on the losses of soil by the gully erosion process because it has a high sensitivity to the degradation process.

The slopes of the semi-arid zone of the Prerif are often pickled up to the rock. It is necessary to underline another aspect of the eroded grounds, the strong variations of diurnal temperatures, the frequency of wetting and drying cycles and the frequency of freeze-thaw cycles on a daily scale, lead to deep cracking of marl materials and marked differences in vegetation, soil and erosion depending on the exposure of the slopes to the sun, drying winds and showers. The Bsabsa slope exposed to the south-east in the central Prerif constitutes a reference model of the gully process (Figure 8).

4.5. From gully to Badlands

The formation of runoff on the slopes is common on the semi-arid slopes of the southern part of the Central Rif; It is at the origin of the genesis and the evolution of erosion forms going as far as gully, on the cultivated soils, the fallows, and the paths, with the exceeding of the infiltration capacities, can be at the origin of the runoff and evolved gully settles (Muxart, Cosandey, & Billard, 1990).

Cartographic work was done before the field mission, which showed us that the evolution of gullies takes place in new areas known as another form of erosion (mass movement), because of its exposure and the importance of vegetation cover. At Kodiat Belayne in Amzaz Wadi catchment in Central Rif, the abandonment of cultivated land with extended fallow promotes the formation of gullies in extension. A comparison in terms of evolution between a mission of an aerial photograph of 1982 (Figure 9), and an

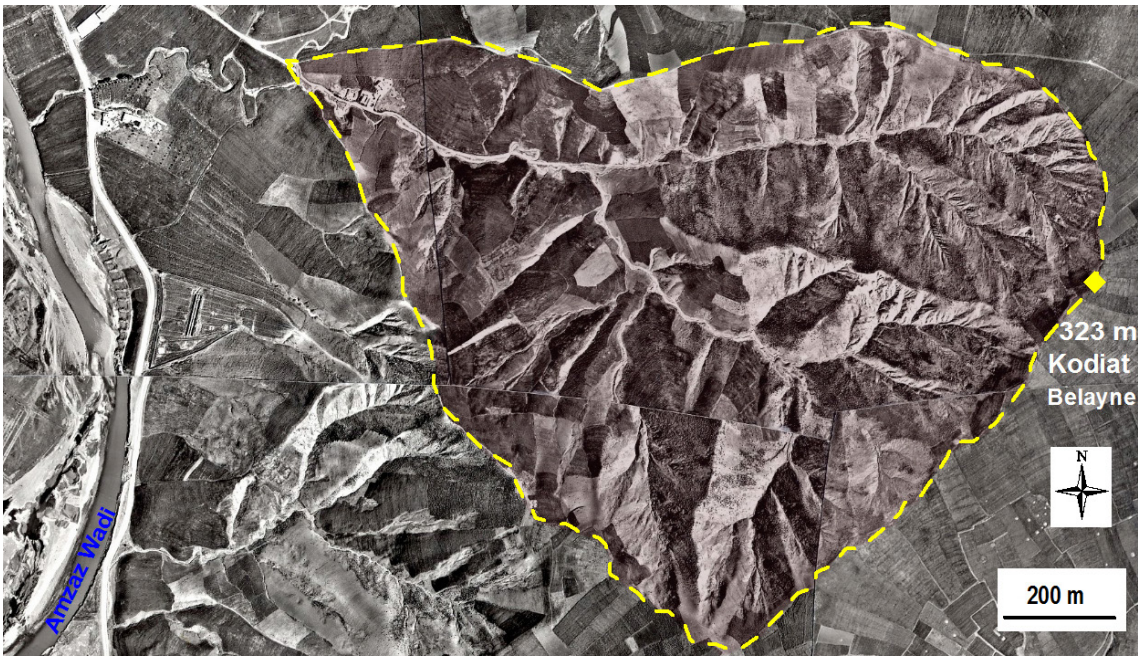

Figure 9
The aerial photograph of Kodiat Belayne gully in the southern Rif mountain area.
Source: Extract from the aerial photo, the mission of 1982

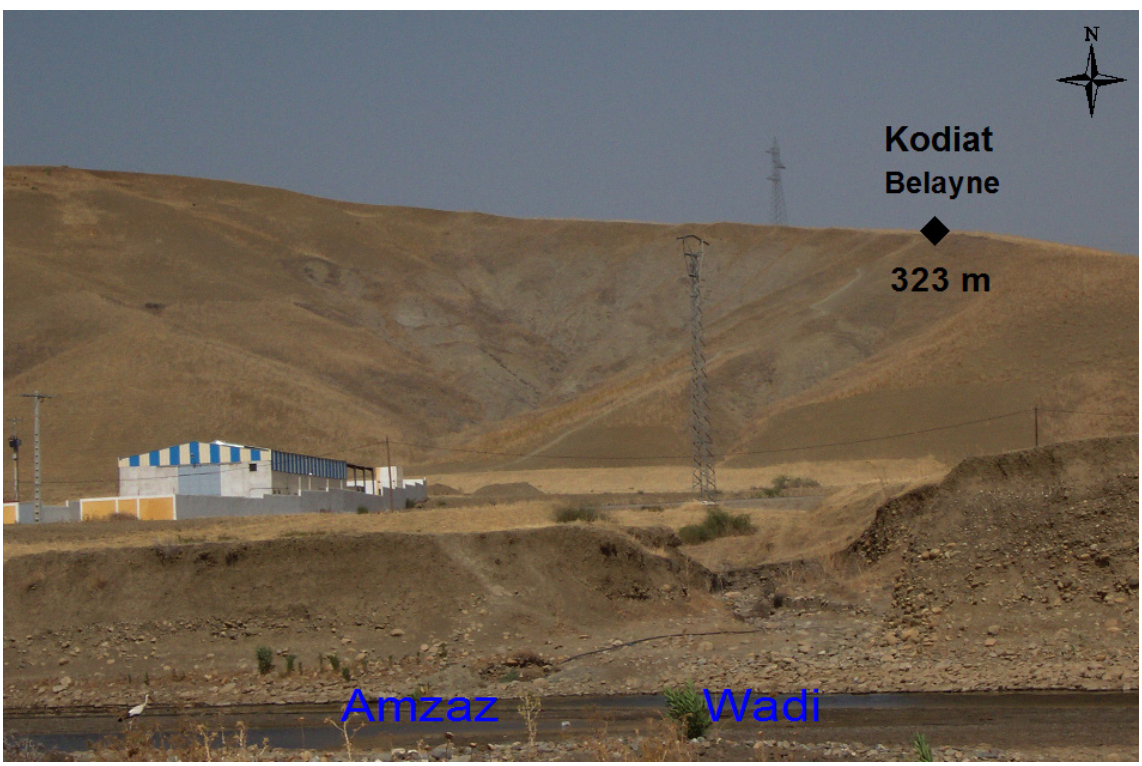

Figure 10
The transformation of the western slope of Koudiat Belayne from gully into badlands in the southern Rif mountain area.
Source: Situation of July 2016

on-site mission carried out in July (Figure 10) shows that:

- The area has been abandoned for over 10 years, and there is no culture on the western slope of Kodiat Belayne, said the owner of the concerned zone.

- The evolution of the gullies to the Badlands was very rapid compared to the previous years according to the inhabitants near the degraded plot.

- The process of evolution becomes multiple, in the form of mass movement and the digging of gullies, because before the abandonment of the land, the cultivation of the slope had helped to correct the elementary gullies before its evolution into Badlands.

4.6. Siltation and solid sediment load

The transition zone between the Rif and Prerif houses the biggest dam in Morocco (Al Wahda dam), which is the first in Morocco and the second dam in Africa with a storage capacity of 3,800 million m3, built-in 1996 (Figure 6), on Ouerrha wadi catchment (Figure 7). Among the construction objectives of the Al Wahda dam is to protect the downstream of the Gharb area from floods, electricity generation, drinking water supply to large cities (Casablanca and Rabat), and for irrigation reasons (Table 1).

Table 1

Characteristics of the Al Wahda dam in the southern Rif mountains.

Dam	Area	Seating Year	Storage capacity	Height
Al Wahda	southern Rif mountains	1996	3800Mm^3	88m

The dam is located downstream of Ouerrha Wadi, which is the most important in terms of annual flow, but it is downstream of the most fragile and sensitive area in terms of erosion. However, the Ouerrha basin drains 2877 Mm^3/year, which is equal to 51% of the water resources in Morocco (ABHS, 2006). This wealth is greatly threatened by the siltation of this large dam.

In the study area, which is characterized by its fragility, the siltation phenomenon is a hydraulic problem that seriously threatens the capacity of Al Wahda dam and/or the satellite dams built to protect its reservoirs downstream (Gartet, El Fengour, Jouad, & García, 2009).

The erosion of the Ouerrha watershed estimated at 98 t/ha/year over an area of 6150 km^2, would cause the dam to lose an annual volume of 60 million m^3 (Agri Maroc, 2001). The alternating periods of drought and humidity that characterize the climate of the Mediterranean (Monteiro, Carvalho, Velho, & Sousa 2013), make a severe impact on natural resources and on infrastructures like a dam (Monteiro, 1988).

The plains located in the foothills of the Rif mountains, the slopes abruptly diminish and the transit capacity of the Wadis from the high mountains or their foothills decreases sharply (El-fengour, 2016).

To demonstrate the transition in altitude, which has a very high impact of production of the sediment load, we carried out a follow-up at a representative section on Amzez Wadi (Figures 11 and 12), one of the tributaries of Ouerrha catchment in upstream of the Al Wahda dam, and also the impacts on human statements.

Hydrodynamic actions are very active in the downstream part of the Rif mountain catchment in conjunction with Ouerrha Wadi, upstream of the Al Wahda dam, these catchments are characterized by steep slopes, ravines, bare, impermeable, and favourably exposed to meteorological disturbances (El-fengour, 2009) and particularly conducive to the development of storm cells, since it is a region where the highest daily maximum rainfall is recorded which sometimes exceeds 1000 mm/day.

The slope angle classes from 25 to 30 degrees show the influence on hydrodynamic stream bank erosion occurrence (El-fengour, 2016). The highest degree (more than 30°) indicating a high probability of hydrodynamic and the erodibility of banks within that slope class in upstream of Al Wahda dam.

In semi-arid climate, occasionally suffers from the great misdeeds of very wet periods, because the aridity favors the appearance of hydrodynamic and violent floods because the absence of vegetation cover supports the runoff that is associated with impermeable lithology in Prerif areas. The average of sediments produced each year is on average 6000t/year in a normal year, and reaches 38000t/year for a wet year (Heusch, 1970).

The quantity of solid sediment load produced varies from one year to another and within the same

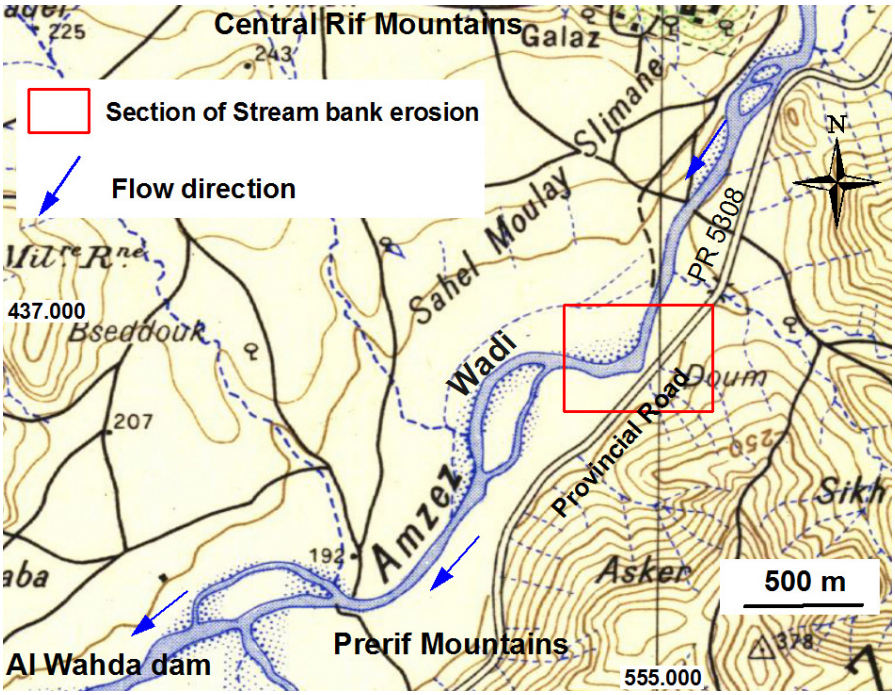

Figure 11
Streambank erosion in Amzez wadi at Galaz section in 1953.
Source: Extract from the topographic map, 1953.

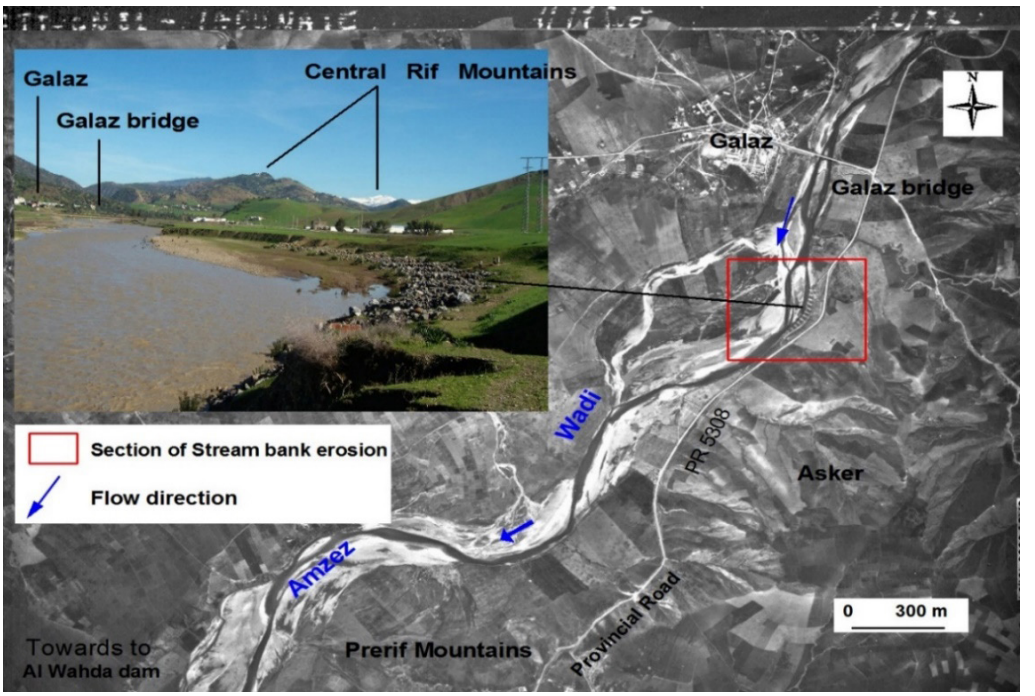

Figure 12
Streambank erosion on Amzez wadi at Galaz bridge section in 1982 and 2016.
Source: Extract from the aerial photo of 1982 and field trip in 2016

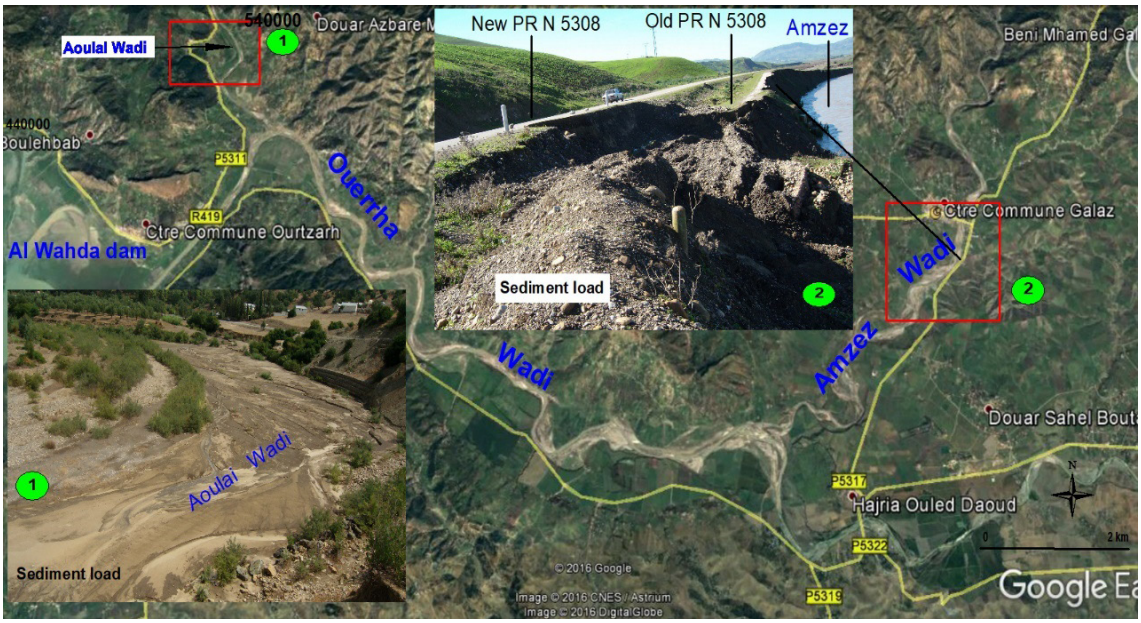

Figure 13
Solid sediment load produced by the hydrodynamic actions and leads directly into the Al Wahda dam in Rif mountains.
Source: Background from Google Earth 2016, and field trip in May 2017.

flood, depending on the flow velocity, slope degree, length profile, flow volume and the lithological structure of the watershed (Figure 13). More than 50% of the materials are transported from the slopes (Table 2). This quantity which exceeds 109.000t/year drains directly into the Al Wahda dam (Heusch, 1970).

Table 2

Assessment of solid sediment and its origin in Prerif area.

Origin of erosion and transport (T/year)	Year			
	Dry	Normal	Wet	average
Slopes	0,02	70	20.300	6823
Badlands	150	3140	20.900	8063
Stream bank erosion	74	2690	67.000	32.521
Total T/Year	**224**	**6000**	**109.000**	**38.408**
Slopes	0.01	3	19	7.4
Badlands	67	52	19	46.0
Stream bank erosion	33	45	62	46.6
Total %	**100**	**100**	**100**	**100**

Source: Heusch, 1970.

5. Diversity of projects and failure of soil management

Among the 20 million ha of watersheds upstream of existing or planned dams, about 5 million hectares pose significant risks of water erosion. With a specific degradation that exceeds 2,000 tons/km^2/year (Minister of Agriculture, 2001), in the Rif region. The development programs and the protection of dams in the Central Rif mountains in northern Morocco against the degradation of the soil are very varied in space and deserve an evaluation effort.

5.1. The national plan for combating desertification

The development will certainly not allow to recover the soil and the totally lost parts. The national plan to combat desertification was prepared in 1986 in accordance with the recommendations of the United Nations Conference on Desertification (UNCOD) in 1977. This plan had two main objectives:

- to analyse the achievements and constraints encountered in the implementation of programs.
- to combat desertification and to propose a strategy to combat desertification.

The plan favoured two priority sectors, namely herding and the supply of wood fuel. Thus, actions had been proposed for each of these two sectors (Korachi, 1995). The implementation of the national plan to combat desertification had specific problems related to the absence of an appropriate institution-

al framework for the implementation of this plan, since these integrated interventions cannot be envisaged, each of the actors has simply continued to conduct its activities as usual without respecting the objectives of the project.

5.2. Integrated development projects

The Integrated Development projects (IDPs), which constitute a global and voluntary option for agricultural public policy, have been involved in a generation of projects promoted by the World Bank in the late 1970s. The IDPs were implemented in a first phase and then extended into favorable areas of the boor. Later, to less favorable regions.

The IDPs covered almost one million hectares and were generally targeted to areas of cereal farming, where extensive livestock production is palpable importance in the traditional farming economy. These projects, in their time, constituted a moment of rupture with the former sectoral policies. The watchword was "integration".

One of these projects is Fez-Tissa-Karia in the Prerif area, which started in 1979. On an area of 354,000 ha with a population of 280,000 inhabitants. The project introduces agricultural conservation techniques (Figure 14) under a pilot program for 70,000 ha for the improvement of uncultivated land with a view to implementing another program afterward.

The project involved the planting of olive trees on an area of 8,000 ha, the afforestation of 3,000 ha with Canary pines, the planting of acacias and eucalyptus on 2,000 ha, the fight against gullying on 3,500 ha (Banque, 1978).

This project has also failed to achieve its objectives, despite the financial and human resources available to the authorities to carry it out in the best conditions. The steep slopes planted by olives, in the province of Fez during the period of the project, disappeared completely on some slopes.

5.3. The rural development strategy

The rural development strategy, by 2020, explicitly traces the new options defined by the public authorities for rural development. It proposes to analyze the strengths and constraints of the rural world in relation to a vision that integrates the imperatives of safeguarding and protecting the

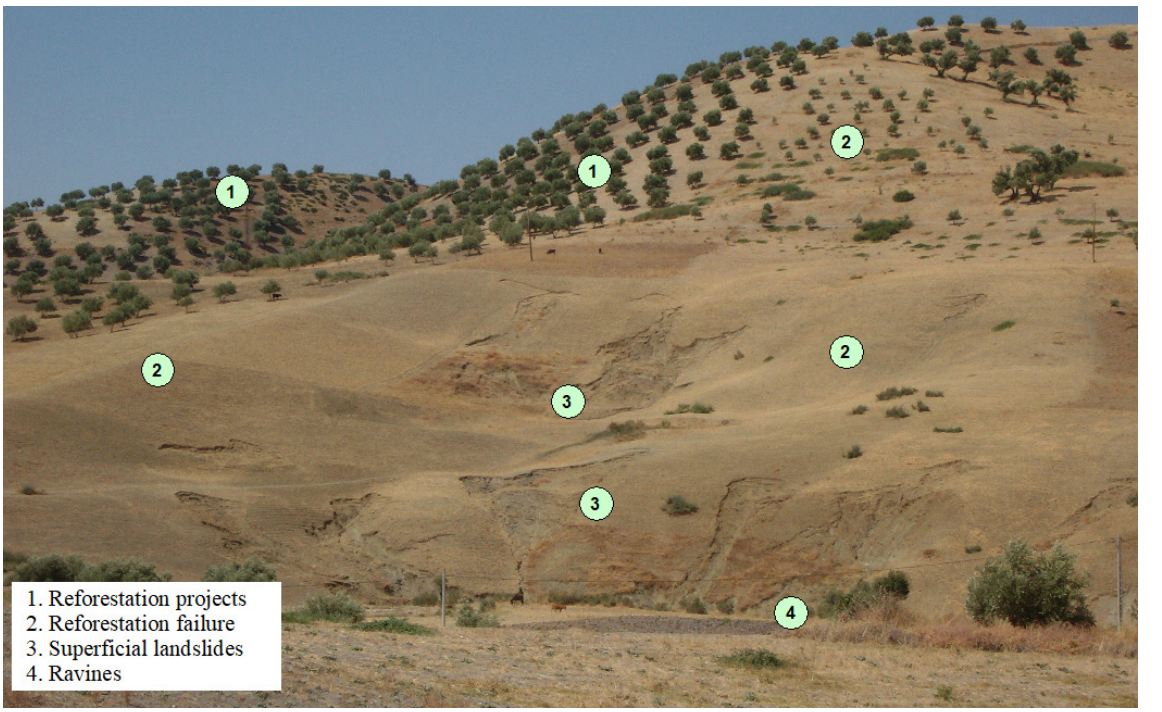

Figure 14
Failed to protect steep semiarid land by olives within Fez-Karia-Tissa project in the semi-arid zone in Prerif area. Septembre 2018 situation.

environment and highlights the possibilities offered by the rural areas, livestock sectors, crafts, tourism, and fishing.

5.4. Reforestation plans

The National Plan of Reforestation was elaborated in 1970 (in the whole country), in order to supply the elements of response to the needs of the country in the production of wood, protection of the soil against erosion and recreation space.

Reforestation Plan, by 2000, envisaged the planting of 662,000 ha divided between 355,000 ha of production forests, 115,000 ha of the mixed plantation (production and protection), 185,000 ha of protective forests and 7,000 ha of recreational use.

The National Plan of Reforestation objective has been achieved only partially, and another plan had started for reforestation requirements were theoretically estimated at 5,000,000 ha. of the Physical, technical, socio-economic and financial constraints imposed a downward revision of this area, leading to a strategic option of reforestation by 2025 of 1,500,000 ha (Goldnick & Moumadi, 2004).

6. Conclusion

The results presented highlight the strong constraint that is exerted on the soil, a constraint which is not only related to the climate, but also to the anthropic action. The vulnerability of the Rif area against degradation is greater, since the 1970s, the pressure on the natural environment has increased considerably under the double impulse of the intensification of illegal Cannabis agriculture and the population growth and aggravated by the impacts of climate change. The management and soil protection strategies in the Rif are both those of the arid zones for which these choices result primarily from the shortage of climatic origin, and those which unfold in the humid part and which are mainly due to deforestation related to the problem of Cannabis agriculture.

This management challenge occupies an important place in the concerns of the Moroccan State, especially in marginalized and fragile areas. Rif mountains or semi-arid and humid climate have experienced soil management projects, but these managements are very varied and not adapted to the local conditions because they are based on a slow acquisition of know-how, and not concerted process.

The failure of resilience, high sensitivity and the inability to avoid and adapt to the adverse effects of climate impacts are serious agents of vulnerability. Irresponsible development procedures also generate vulnerability and imminent exposure.

Soil conservation projects should, therefore, go beyond the framework of specific interventions dictated by the particular conditions of a given sector for sensitization, a partnership with downstream stakeholders (farmers, local actors, and NGOs) and an extension of environmental information that one can have a much better appropriation in the population concerned.

Acknowledgment:

This work is carried out within the framework of the project Reclimplan within the Ibn Khaldoun program for scientific research in Morocco, in partnership with the University of Porto in Portugal, the Institute for Geosciences and Geography at MLU in Halle in Germany, coordinated by the University Mohamed V in Rabat, Morocco. Anonymous reviewers are thanked for their comments and suggestions.

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