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Erosion and Flooding Risks in the Marly Basins of the Eastern Prerif Mountains (Morocco): A Response to Exceptional Climate Events or to Anthropogenic Pressure

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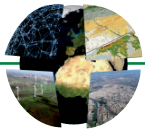
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By its geographical situation in the Mediterranean basin, Morocco is marked by a strong rainfall irregularity which generates very violent hydrological behaviors, particularly in the catchments characterized by topographical, geological and anthropogenic factors which accelerate the genesis of extreme flows. The frequencies of these phenomena and their serious consequences constitute a crucial problem for sustainable development and regional planning in Morocco. They reflect a high degree of vulnerability which often shows human involvement and responsibility for the catastrophic events linked to erosion and flood crises. The Eastern Prerif Mountains, carved mainly in tertiary marly rocks and almost completely denuded, are increasingly concerned by such rainy episodes that cause extreme flows leading to intense erosion on the slopes and disastrous floods downstream of the basins. This situation is reinforced by a strong human pressure on the slopes and by an increasingly aggravated occupation of the sites at risk, due to a rapid and uncontrolled urbanization of the peripheral zones of the agglomerations. This contribution synthesizes the research works done in the region, during the last two decades, on the phenomena of runoff and erosion. It aims to present and analyze the combined impacts of the extreme rainfall events and the actions of the human societies, on the dynamics of the prerif environment and its adjoining spaces. The aim is also to deepen the understanding of the functioning of this environment and to contribute to the various debates and projects concerning regional planning and the fight against disasters caused by natural hazards.

To analyze this question, our methodological approach is based on the implementation of a set of tools and sources of information. The climate study approach relies on the use of meteorological data relating to a series of rainfall measurements in both Taza and Had Msila station for the period (1970 - 2016). Similarly, time situations were analyzed by referring to the weather maps provided by the German site www.Wetter3.de, which allowed us to follow the temporal evolution of the disturbances during the rainy events. The historical dimension of this study was approached on the basis of bibliographic research; also, administrative records and reports have been helpful in supporting our results from the field. Surveys and fieldwork allowed us to verify and complete the photo-interpretation, concerning details of the natural and anthropogenic causes of erosion and flooding phenomena. The RUSLE model integrated into the Idrisi software allowed us to evaluate the average annual rate of erosion in some sub-basins of the region, according to



the distribution of rainfall aggressiveness, soil erodibility, topography, land use and crop management practices. In addition, the dynamics of infiltration and runoff according to soil surface conditions was tested by using rainfall simulation on micro-plots (1m²) using a mini-simulator with rainy ramp with simulated rains of 50 mm and intensities of 80 mm / h. Before each simulation, the surface condition of the parcels concerned is checked. It is a question of raising the rate of closed, open and covered surfaces, according to the quadrats points' method.

The results of this study show that the aggressive nature of the exceptional rains and their pronounced concentration during short periods of the year create imbalances manifested in excess of humidity, with all their implications in the dynamics of the environments. They intervene directly in the mechanisms of erosion and flooding and influence the effect of water aggressiveness at the watercourse level. Despite the recurring droughts that characterized the last decades, some years remain largely wet with occasional torrential rains that discharge large amounts of water in short periods. These exceptional events are related to weather situations due to oceanic disturbances or only to localized thermo-convection storms. They are assimilated in some cases, but with a smaller magnitude, to heavy precipitation events (HPE) which affect frequently the western Mediterranean basin and which are part of the major natural risks causing serious consequences for environments and populations. The impact of these phenomena on environments is more important as the slopes are bare and subject to strong human influence. These mountains are an old demographic home where the components of the physical environment have undergone significant changes, of which man bears a large share of responsibility. Researches conducted during the last decades, in different regions of Morocco, confirm the extent of these transformations in all Moroccan countryside during the 20th century, with serious consequences for environments and societies. The traditional structures as well as the old socio-spatial organization have been largely shaken, and the balance, long maintained between the needs of the populations and the local resources, deeply broken. If the colonial era was marked by an alteration of the traditional model of organization of resource use; the period of independence shows a strong population surge leading to an exacerbation of the human influence on the environment.

This human pressure, to which various land use methods are linked, explains to a large extent, the intensity of environmental degradation. It has resulted, on most sides, in very spectacular agrarian conquests. In this context some forests were totally destroyed during this period and converted back to farming land. The current use of space reflects the extent of human influence and agrarian conquest. Land structures, shaken by various historical events, introduce varieties of occupation, some of which are incompatible with the conditions of the physical environment. Similarly, demographic pressure has transformed forest landscapes into a mosaic of cereal plots associated with degraded scrub (matorrals). Protective natural forest slopes are almost destroyed; they currently cover only a few mountain peaks in the region. They represent respectively 1.84% and only 1.32% of the total area of the Tleta and Tarmast sub-basins of Wadi Larbâa. However, croplands, occupying respectively 60% and 34% in the two sub-basins, extend even on the steepest slopes. Similarly, the accelerated and uncontrolled human occupation of the urban peripheries, located downstream of the basins, increases the vulnerability of this environment to the hydrological hazards that threaten several peripheral sites in the Taza agglomeration. Thus, the progressive concentration of the population in the city reflects the importance of the dynamics that it has experienced in recent decades, to the detriment of the surrounding rural areas which clearly display a growth rate, which has been steadily declining since the 1980s because of the recurrent droughts. This demographic transition, characterizing the last decades, has been associated with a development of the urban fabric in an anarchic and uncontrolled way, which explains the magnitude and severity of the installations in carrying risk zones. This uncontrolled human occupation has significantly worsened the intrinsic fragility of these sites. Also, the lack of basic infrastructure, the overdensity, the elevation of some buildings, the non respect of building standards and the lack of maintenance constitute some factors that amplify the vulnerability of these environments to natural hazards.

In this prerifan area, soil erosion is a crucial problem that threatens the economy of the region and destabilizes the lives of local population, already precarious. The intense erosion processes on the marly slopes as well as the extremely rapid evolution of the gullies, degrades the soil capital and allows evacuating huge quantities of sediments annually to the main collectors, threatening the road and hydraulic infrastructures,



and residential districts. Quantitative assessment of water erosion, using RUSLE model, shows that average soil losses are well above tolerance levels, although they are close to national and regional ablation rates. In the case of the marly sub-basin of the Telata wadi, the weighted average loss by the surface is $61 \text{ t ha}^{-1} \text{ year}^{-1}$. The losses are greater in the Wadi Tarmast sub-basin where the losses are about of $81 \text{ t ha}^{-1} \text{ year}^{-1}$. The soil losses according to land occupations in 2014 shows that uncultivated and abandoned land still remain in the lead with $140 \text{ t ha}^{-1} \text{ year}^{-1}$ for the wadi Tarmast sub-basin and $108 \text{ t ha}^{-1} \text{ year}^{-1}$ for the same period for the wadi Tleta.

Rainfall simulations show that the influence of human activities, through traditional land use systems, is very significant in terms of the nature of the flow infiltration and ablation processes. Plowed soils record low runoff coefficients compared to those of fallow or totally abandoned land. The combined effect of cropping techniques and plant cover on worked soils can significantly reduce runoff and erosion compared to abandoned land. It seems that the frequency and intensity of runoff on the different types of soil are largely explained by the parameters of the surface conditions (roughness, open surfaces, closed surfaces, covered surfaces, etc...). The rapid compaction of abandoned land, in the lack of any tillage favoring infiltration, allows a concentration of runoff leading to a dense network of incisions. Silty-clay regolith, developed on Miocene marls show, in fact, high runoff rates in late summer and early autumn that can exceed 68% with a solid load of 239 g/l at the end of spring, 179 g/l at the end of winter and 275 g/l at the beginning of autumn. This clay regolith is sensitive to the shear forces which tear the soil from the bottom and allow the installation of gullies. The evolution of the gullies and their annual widening, by different morphogenetic process, makes it possible to produce landscapes of badlands which evacuate most of the sediments towards the main collectors.

Likewise, the enormous human and material damage of the floods, during these last decades, also remind us of the extreme fragility of the urban fabric of the peripheries in the face of this new climatic trend. Uncontrolled urbanization, which developed during the 1980s, encroaching on the minor beds of water-courses, increased vulnerability to the flooding hazards. Several anarchic and unhealthy urban entities are built on the margins of regulation, in the absence of a rigorous policy on urban management. Thus, the public authorities must take the necessary measures to implement and apply the provisions and forecasts of urban planning documents. Similarly, any urban planning must pay particular attention to risk areas, particularly in peripheral zones, in order to avoid or at least reduce the damage caused by recurring flood events in the region. Similarly, in order to face these problems, it is of great importance for the concerned actors to rethink traditional systems of spatial planning. This requires the implementation of a bold strategy to address the past urban errors, in order to prevent the increase of human settlements in areas at risk.

Finally, it should be remembered that the causes of the dysfunctions imposed to cities and the problems they face, are also to be sought out, and in an urgent and priority way, beyond urban perimeters. The development of the poor and deprived countryside, which constitutes the hinterland of urban agglomerations, is more necessary than ever. These fragile and repulsive environments need sustainable development capable of fixing local populations and minimizing migratory movements. Similarly, the development of water resources, which is a determining factor in the stability of these countryside, remains a national priority that any rural development policy must take into account in order to face the serious consequences of any possible environmental crises. Similarly, watershed management and anti-erosion control require the integration of operations within the framework of a global rural development policy in the region, setting the objective of being compatible with physical and socio-economic conditions of this environment. This implies a renovation of the agrarian economy and a change in existing structures. This requires a modernization of the exploitation means and the imperative creation of other sources of income which can provide the local population with subsistence means. These measures would be likely to revalue the rural world, to meet certain expectations of local populations and consequently to reduce the magnitude of the emigration flows towards the surrounding cities.