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ENVIRONMENTAL VULNERABILITY AND AGRICULTURE IN THE KARSTIC DOMAIN: LANDSCAPE INDICATORS AND CASES IN THE ATLAS HIGHLANDS, MOROCCO.

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ABSTRACT
After the brief presentation of the major karstic areas in Morocco, the article focused essentially on the Atlas mountains to investigate the impact of the agriculture on the natural systems equilibrium. Socio-economic changes (demographic pressure, escalation of the landscape use, utilisation of new techniques in water harvesting, etc...) have sometimes fathered mechanisms of degradation. Many indicators seem to reflect these mechanisms. The pedologic indicators, soil erosion, the hydrologic and geomorphic indicators, are apprehended to demonstrate existent correlation between different variables and the often negative impacts of land over-use in the karstic domain of the Middle Atlas.

KEY WORDS: Morocco, Karst, Atlas, agriculture, impact.

1. Introduction

The karst landforms are dominating over the Atlas mountains because of the high occurrence of the Mesozoic and Cenozoic carbonate rocks. These are mainly forming in the Liassic limestone and dolomite, folded and elevated by Tertiary tectonic events and neotectonics. Densely populated, the Atlasic domain is progressively under stress as human needs are exceeding natural resources. The perpetual adaptation to intense human economic needs determine net landscape vulnerability as most Atlasic natural systems are fragile.

The relative equilibrium of the system, acquired from previous adaptations of the traditional human communities (the extensive farming and catlle-breeding), is disturbed in the present-day context. Humans degrade portions of the environment while doing intentional alterations (creative destruction) and may contribute unintentionally to land degradation (Johnson and Lewis, 1995). Regarding the progressively dense settlement of tribes and the intensively engaged agricultural activities, the natural resources in the Moroccan karstic domain are under stress. The vegetation, land and water uses are obviously affected by such activities. Consequent system's imbalance, then, appears.

Multiple disequilibrium indicators were observed while studying the geomorphic dynamics recently developing within this area. The human-induced sediment erosion and sediment transport along artificial streams, the fluctuating discharge due to damming of streams and tributaries "seguias", the abusive irrigation and water supply due to modern crop types, the deforestation, the multiple boreholes managed within the karstic plains and water pollution due to domestic sewage and soil chemical fertilisation are indicators of such environmental degradation initiated by human action. In environmental geomorphology and resource conservation, these processes may reach catastrophic thresholds (non reversible) if the present-day trends are maintained in the future.

The main topic of this contribution is to apprehend the relationships between some active geomorphic, environmental aspects and the anthropic action in the karstic domain of the Moroccan Atlas mountains. This is a relevant question, as sustainability is becoming a respectable concept and a priority in local development and rural management. A brief description of the main Moroccan karst fields is presented, and followed by the discussion of the human context and anthropisation. The land use - landscape disequilibrium interface is studied in terms of indicators analysis to show trends in the landscape degradation.

2. The most typical karst of Morocco (fig. 1)

A bibliographic review related to the Mediterranean karsts (including the Moroccan ones) have been published by Julian et al. (1978). But more works were done ever since. The surface karstic forms of the Atlas mountains have been studied and well known following works of geomorphologists such as Couvreur (1981), Weisrock (1980), Martin (1981), Ghazi (1987), El Khalki (1990) and Perritaz (1995) for example.

Large numbers of karst features were developed in the Middle Atlas plateaux, in the folded Middle Atlas and in many areas of the elevated plateaux of the High Atlas such as Aït Abdi, Assif Mellouln, Assif Ahansal and Imadghas. The high karst of Aït Abdi plateau is situated at an elevation of 2200 m to 3000 m and it is named "a perched karst" by Perritaz (1995). The snow action is predominant so that most karst forms on a such elevation are nival. Large to small dolines, uvalas, poljes, lapiez (karren), blind and dry valleys, incised canyons, plains, rock-fans, and diverse surface solution sculptures were reported in many areas of the Atlas.

Tennevin (1978) reported that the karst topography of North East Middle Atlas "shows highly diversified forms: the plateaux of Ahermoumou, where it takes on superficial forms and activity is reduced; the rocky cones, giant sink-holes and snow wells of Jbel Bou Iblane; the regions of Chara and Ademmane, riddled with sinkholes and full of underground rivers". He emphasised its complex genesis as karstification was guided by tectonics, fluctuating hydrology and paleoclimatology.

The underground karstic morphology and processes in Morocco are less apprehended even if their study begun many decades ago. The "Speleological Society in Morocco" has been set up in February 1948 following efforts of individuals who contribute to the Moroccan speleologic research. Deepest holes were located and mapped in the Rif and the Atlas heights. More than 330 subjacent karst phenomena (caves, caverns, holes etc...) were listed within the Atlasic domain (D.H., 1981). However, the most developed caves are the Toghbeit cave in the south of Chefchaoun (900 m depth), the Wine Tmadouine (Wit Tamdoun) underground river

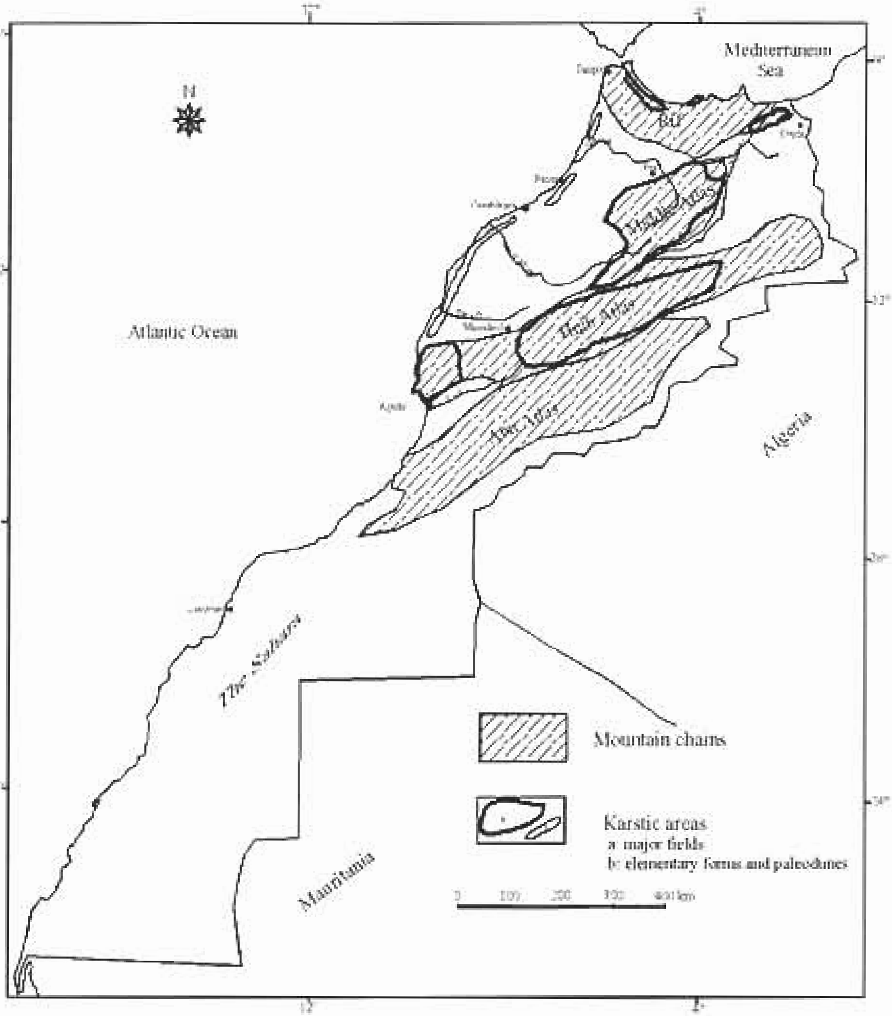

Fig. 1. Location of the main karstic areas in Morocco.

(6 km long) in the western High Atlas, at the north west of Agadir, the Friouato and Chiker underground system in Taza region were discovered early. More recently the caves of the central High Atlas, such as Akhiam cave in the high Assif Mellouln were explored (Calandri and Ramela, 1990).

The physical context controls landscape and environmental equilibrium. The climate is diverse due to complex factors (topography, exposition, elevation, air dynamic masses, etc...). Some increase in aridity from the West to the East and from the median summits to the South is a common characteristic in the Atlas. The subregions vary from humid (Azrou - Ifrane Region), to sub-humid, sub-arid and arid areas (steppic southern flanks). Even in the median Atlas, local depressions could be dried by the foehn or the south-eastern dry winds (Chergui) blowing from the desert. The southern flanks of the Atlas are more affected by the present-day climate conditions with low rainfall and high evaporation.

Considering the main role of hydrology and climate in karst processes, some major landforms indicate a changing and episodic genetic history. The paleo-karst processes are apprehended basing on the quaternary chronology of terraces and links between karst landforms and related carbonate deposits (tufa and travertine). The Pliocene is for example an episode of intense carbonate solution in the Middle Atlas as major amounts of exported travertine were precipitated in the surrounding lower pediments "Dir" at Sefrou, Imouzzer Kandar and El Hajeb regions for example (Martin, 1981). This is in agreement with Nicod's assumption (1994) confirming paleo-karst processes in more than one case in the mediterranean area. The tectonic events have been considered among explaining factors of various lakes in the Atlas highlands. In the median High Atlas, Couvreur (1981) reported sedimentologic indicators of a mid-quaternary lake in Tizi-n-Tghza due to the Aït Bougmez valley obstruction, following tectonically destabilised slopes. After El Fellah (1994), the lake Tamda in the Middle Atlas (upper Melloulou, Guercif) fit in a similar explaining model (karst processes activated by tectonic effects). Debris flows and mud flows could also obstruct valleys and generate lakes' formation as observed on the Djbel Izourki flanks, where the lake Izoughar has been formed (Couvreur, 1981).

Current carbonate dissolution rate, as estimated from water analysis, is seemingly slow. It is approximately above 25 mm/1000 years as calculated for the upper basin of Oued Sebou, Middle Atlas (El Khalki, 1990). It is presently a very localised and less perceptible dynamic.

3. The human context and anthropisation

3.1. *The favourable context of change*

Agents of landscape transformation are of physical and anthropogenic kind. The human and socio-economic factors are however more efficient in the changing processes during the last two decades. The Atlas mountains were subject to two basic driving forces: the local population increase and the national market vegetable needs, commercialisation and investments (external forces). Human settlement is ancient in the Moroccan highlands as indicated by human neolitic traces in caves (e.g. El Hajeb and Imouzzer Kandar). Very important sites of paleolitic instruments and silex pebble presenting human sculptures have been observed in the vicinity of Aguelman Sidi Ali (Middle Atlas) and on the plateau of Azrou.

In most areas, the natural resources abundance provided an ideal environment for human settlement within a peculiar adapted system of nomadism (seasonal movements between the summits "Almou" and the borders "Azaghar") and traditional farming and cattle-breeding (Table 1).

The fact that the Moroccan highlands were until recently less populated is noticeable. Rural population density in the Middle Atlas for example is generally under

seasons	farming works	breeding activities
autumn	labour, seeding wheat and barley	Herd / to "Azaghar"
spring	maiz seeding in "Azaghar"	Herd / back to "Almou"
summer	harvesting	Grazing / forests

Table 1 - An outline of land-use in the Middle Atlas at the century beginning (after Chahhou, 1992).

20 persons per square kilometre. Many mountainous parts are still human deserts. The most important villages are grouped along valleys, rivers and springs. The rural landscape shows typical adaptation to karst landforms in several cases. As reported from other Mediterranean karst areas (Nicod, 1982), the farmers seek the best potential soils, the low platforms and topographies of the karst depressions and manage adapted parcels called "Jardins du Karst", "doline-champs", "doline à terrasses" and so on. Their flat bottoms are generally cultivated (Fig. 2). However, this is the first

Fig. 2. The dolines bottom is often adapted to agriculture, as observed in the large depressions between Imouzzer and Ifrane.

step of land use in the karst areas. It proceeds what is seeming to be the new tendency as characterised by soil reclamation even on the rocky degraded surrounding flanks (Fig. 3).

However, the three last decades witness considerable population growth and an urbanisation process is presently active in the area as observed from examples given in Tables 2 and 3.

The valleys where traditional agro-pastoral activities were practised and the sum-

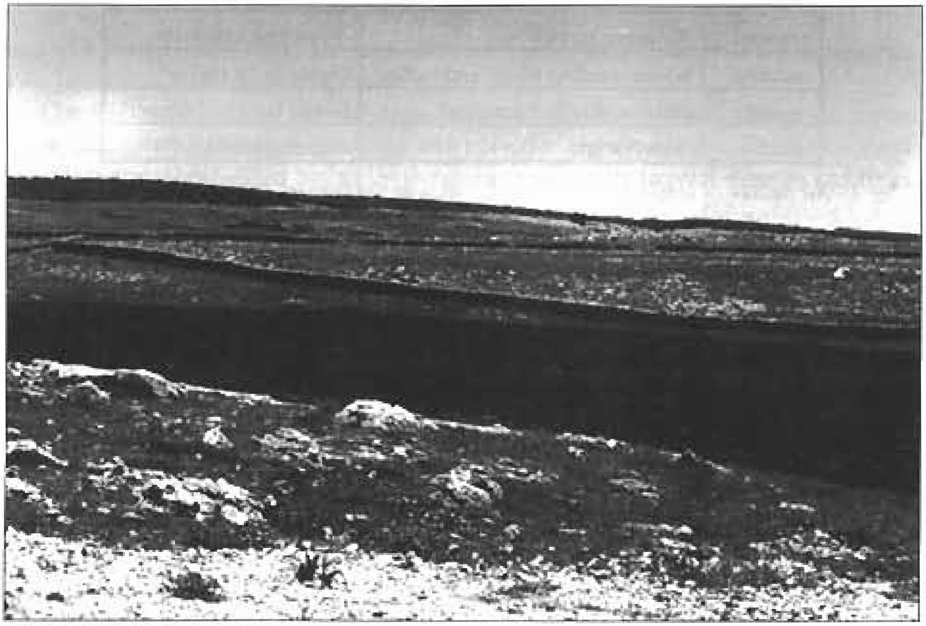

Fig. 3 - On the Ifrane plateau, the land reclamation process consists of enlargement of arable land areas, either on behalf of forests or by managing uncultivated lands using techniques of crusts' dislocation and karren substrates levelling out. The dislocated blocks are used to build long walls on the fields' limits.

mits and overlying landscapes where extensive nomadism took place are recently changing because of the several incentive factors that rouse the intensive agriculture

Rural district	Geographic location	Population in 1971	Population in 1982	Population in 1994	Total rate increase 1971-1994 (%)
Ait Serhrouchene	Middle Atlas	12768	15704	10501	34
Zerarda	Middle Atlas	7879	9182	9734	23.5
Ait Bazza	Middle Atlas	3761	3668	5281	40.4
Almis Marmoucha	Middle Atlas	2376	2350	2689	13.1
Guigou	Middle Atlas	10607	13422	10808	1.8
El Mers	Middle Atlas	5768	5660	6050	4.8
Skoura	Middle Atlas	5979	6896	8010	33.9
Talzemt	Middle Atlas	4277	4381	4307	0.7

Table 2 - Population increase of some rural districts in the Atlas mountain area. Source: based on the results of the general censuses of population (1971, 1982, 1994).

Urban centers	Geographic location	Population in 1971	Population in 1982	Population in 1994	Total rate increase 1971-1994 (%)
Ain Leuh	Middle Atlas	3403	4202	10501	208.5
Azrou	Middle Atlas	20756	31471	40808	96.6
Bhalil	Middle Atlas	6633	7219	10678	60.9
Boulemane	Middle Atlas	1964	3295	6067	208.9
El Hajeb	Middle Atlas	12601	16728	23369	85.4
El Menzel	Middle Atlas	4719	6617	10785	128.5
Ifrane	Middle Atlas	6014	7717	11209	86.3
Immozzer Kandar	Middle Atlas	4474	7018	11555	158.2
Ribat El Kheir	Middle Atlas	2020	2494	8373	314.5
Sefrou	Middle Atlas	28607	38833	54163	89.3

Table 3 - Population increase of some urban centers in the Atlas mountain. Source: based on the results of the general censuses of population (1971, 1982, 1994).

expansion. Among them are the following factors:

1) the abundance of water resources. The Atlas, particularly the Middle Atlas was considered to be the natural "Moroccan water reservoir" with regulated and permanent rivers and springs discharge flow. However, the advantage issued from this hydrologic factor is presently shifting as resources are already over exploited in some cases;
2) the fertile soils, mainly in the karstic depressions, where thick soil profiles are acquired from a long term carbonate dissolution and humus accumulation;
3) the population growth due to the demographic "explosion" and emigration;
4) the economic factors attributed to the higher added-value issued from modern activities. The profits resulting from modern agriculture in some mountainous areas attracted more considerable investments;
5) the increase in demand of foodstuffs due to the demographic growth and the new cultural attitudes which intensified needs to foodstuffs;
6) the commercialisation network and market development;
7) the government's encouraging acts. Many decisions oriented to support agriculture and rural development have been adopted in terms of credits, financial aid, exemption from taxes, technical assistance, etc...

3.2. *Rural development and landscape change processes*

Developing actions sponsored by the government, the communes and private individuals contribute intentionally to the landscape structure and change in the Atlasic karst domain. They consist of multiple irrigation projects, drinking water providing program for rural communities (The P.A.G.E.R. program), rural electrification (The P.E.R.G. program: Programme National de l'Electrification Rurale), rural disenclavement (rural roads network) etc... However, the most important change process appears in agriculture. Even the traditional agriculture (which is a production system evolving when the marginal productivity of labour is very low) is still dominating in the upper lands and summits of the Atlas, it is, however, gradually shifting in the western and northern Middle Atlas as intensified land use becomes a main fact.

Uncultivated lands are reclaimed and underutilised lands are subject to growing productivity actions. The last two decades have witnessed an unparalleled revolution in development, dissemination and adoption of new agricultural technology. These actions aim to develop high yield crop varieties and more efficient agriculture.

Apple trees, pear trees and peach trees are the dominant trees adopted in recent plantations. Badidi (1995) shows that within the last three decades (1964 - 1994) their area have been considerably enlarged (Table 4). Their allocated surface is approximately 22400 hectares in The province of Sefrou (including an important proportion of olive trees plantations), more than 4100 hectares in Ifrane province (fig.

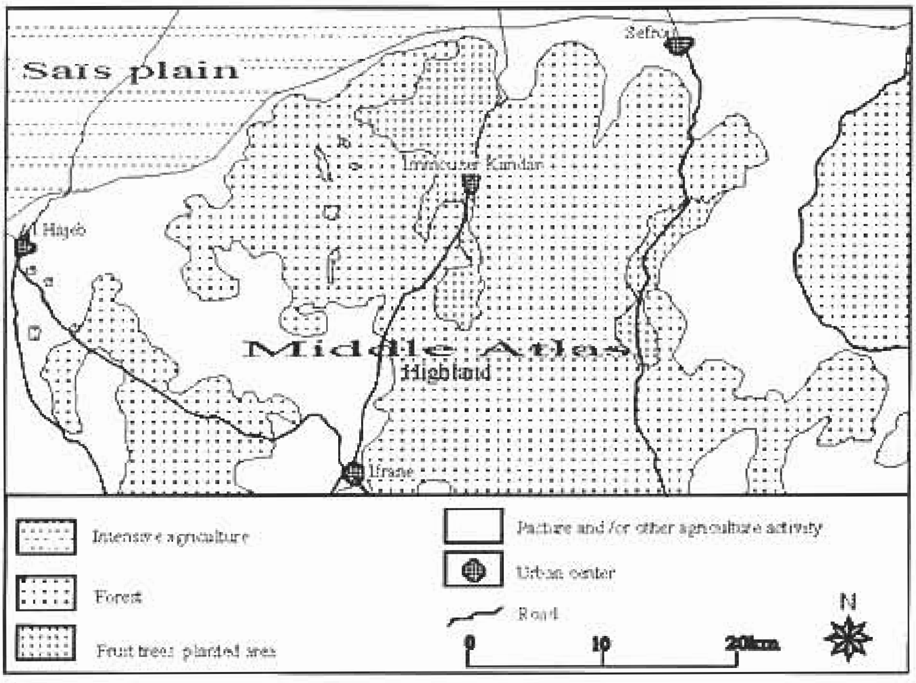

Fig. 4 - The main fruit trees planted areas in the Northwest of the Middle Atlas.

4) and 9000 hectares in the Province of Khenifra. A peculiar landscape changing process has been linked with the farming development as land reclamation, crusts dislocation and resources waste took place.

Such agriculture is a highly water consumer and becomes inadequate without irrigation. Most farms are irrigated either by turned aside waters from rivers, springs, or even by wells lowering progressively the underground water table. Such a problem is seasonally emerging in several regions (Guigou, Amekla plateau etc...), generating occasionally severe social conflicts.

	1964	1974	1984	1994
Immouzzer Kandar	200	926	1236	1700
Irklaouen district	450	778	1450	1882
Amekla	36	82	389	450
Aït Oumghar district	14	223	846	1400

Table 4 - Evolution of the planted area by fruit trees between 1964 and 1994 (in ha) in some districts of the Middle Atlas mountain (Badidi, 1995).

3.3. *The impact of social stakes on karstic landscape degradation.*

Social facets of land degradation are generally accepted in environmental studies (Blaikie and Brookfield, 1987; Johnson and Lewis, 1995). The historical and socio-political factors are important in environmental change of the Moroccan mountain including the karstic areas. A fragile land property status has been acquired from a long term history of tribes' struggles, dramatic events and sometimes agreements on landscape cuts and commons definition. However many sites of social tension are presently still existing in the marginal areas and borderlines between tribes and local communities. They are vulnerable and witness environmental adjustments depending on the historical events and acquired social equilibrium either horizontally (between different ethnic groups) or vertically (within the same tribe). In most cases, ecosystems disequilibrium is setting off as natural resources are over exploited by individuals or even groups in the absence of any governance of the community. Either agreements and conflicts on lands appropriation and land use have complex effects in terms of environmental equilibrium, leading sometimes to what investigators call the "tragedy of the commons" (Bencheriffa and Johnson, 1991; Johnson and Lewis, 1995).

Several examples of such situation have been observed within the Atlas mountains. They illustrate how further the social impact may be in terms of environmental equilibrium. The case of Skoura - Mdez management project may be presented here as a typical example.

The project aimed to create a modern irrigated agriculture in Skoura depression (Province of Boulemane, Middle Atlas) at the expense of the forest domain (an area of approximately 1400 hectares). Series of enactments have been decreted since 1953 (Dahir of January the 28th, 1953; followed by a ministerial decision in June the 25th, 1959 which brought precision on criteria and procedures of land distribution). A systematic deforestation began and a network of irrigation canals have been built across the depression. The project blockage emerged soon when the conflict started between the neighbouring tribes (Aït Seghrouchene and Aït Youssi). The list of beneficiaries was prepared among retired resistants and military servicemen from Aït

Seghrouchene. That fact was not allowed by Aït Youssi who plead common rights on a land they considered to be theirs. Consequent deterioration of equipments, land degradation, soil erosion and bad-lands forming are presently active processes in the area.

4. The land use - landscape disequilibrium interface: indicators of landscape degradation.

4.1. *The pedologic aspects*

1. Soil types, soil scarcity and land reclamation

The physical framework of the Atlas mountains induces a noticeable soil scarcity. Most calcareous semi-arid flanks are initially without any soil cover except in fractures and local depressions. Due to climatic conditions, the geomorphic factors and the hydro-karstic activity, the thick soils are generally concentrated in the bottom of karst depressions.

On the calcareous and dolomitic Atlas flanks, most surfaces are rocky or covered by rock-debris soils, over rock layers at depths of 10 to 50 centimetres. Only in collecting topographies (karst depressions) and valley terraces, full profile soils with A, B and C horizons of more than one meter thickness can be observed.

The existing soils in the Moroccan Atlas highlands are several types. In general, the upper zone (> 2200 m in elevation) is composed of steppic soils. The middle zone (1800 - 2200 m) is mainly composed of brown forest soils and locally red-iron soils. The Terra-rossa and typical red-soils widespread however in the lower mountain and on the Atlas borders (locally known as "Dir"), due to soil erosion / deposition from the upper zones and the locally karstic activity. Such processes generate clays and red specific soils known in the Mediterranean area as "Terra rossa", called "El Hamri" in most regions of Morocco. Their favourite locations are generally valley - terraces, topographic micro and macro depressions, diaclases, fractures, karren, lower pediments and plains forming a surrounding belt of the Atlas mountains.

The links between karstic hydrology, topography and sedimentation allow sometimes a diversity in pedologic processes. The white coloured soils observed locally in the "Dir" and on the Atlas flanks are in fact soils enriched in carbonates. Tufa and travertinous deposition, caliches and the carbonate enriched waters affect soils' colour. When dominating within the profile, such material allows the genesis of white (carbonate enriched) soils locally named "Biada".

Studies of terraces and valley deposits (eg. Couvreur, 1981; Martin, 1981) argue that most of them are either Holocene or Wurmian in age (Rharbian or Soltanian in the Moroccan nomenclature). Soil types and soil allocation in the Atlas reveal, therefore, a fragile and vulnerable equilibrium.

The present day land use and land reclamation process affect the acquired fragile equilibrium. The land reclamation consists of enlargement of arable land areas, either on behalf of forests or by managing uncultivated lands using techniques of crusts' dislocation and lapiaz substrates levelling out (Fig. 5). Such operation has been

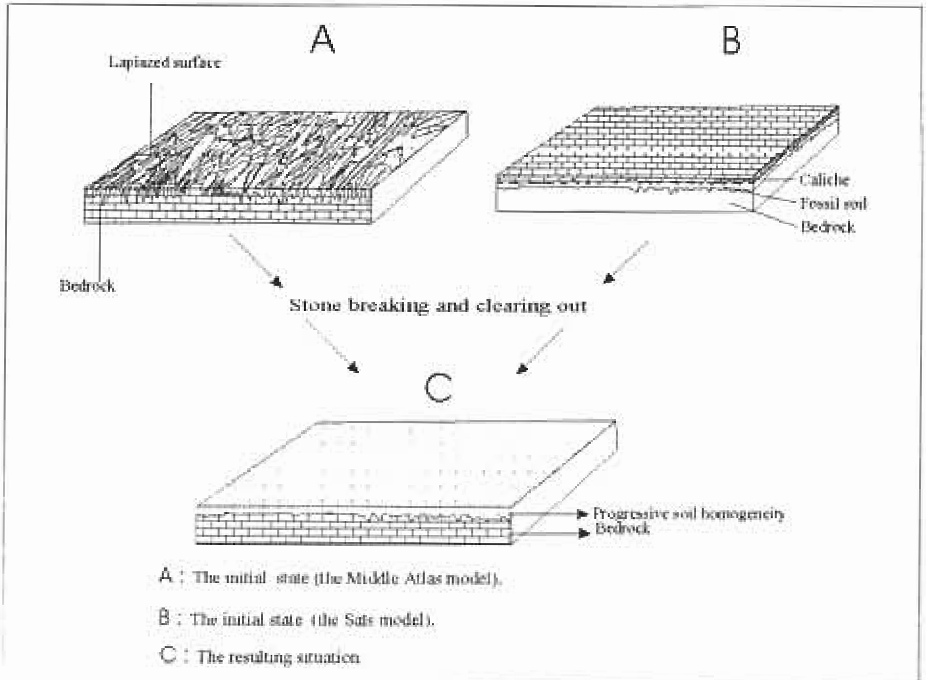

Fig. 5 - Agriculture, lapiaz and soil reclamation in Saïs and the Atlas mountains: a simplified model.

encouraged by the government at the beginning of this decade.

The soil scarcity over the Atlasic flanks is subsequent of the initial system's dynamics within the karst areas. The genesis of irregular topography (lapiaz, dolines, uvalas, polje, etc...) tends to concentrate residual and detritic material and therefore soils in the lower sites. In order to reach the hollow sites, to reduce the field's surface roughness and to adapt it to the use of modern agricultural instruments, the surface blocks are often broken and carried out to fields borders (Fig. 3). The topography tends to be more homogenous and covered by soils recuperated from above and below destroyed rocks. Hypothetically, new basis of equilibrium should be sought by the system because new landscape, new hydrologic conditions and new human context have been imposed.

2. Soil destructuration, soil erosion and swallowing

Two directions have been observed in soil erosion and sediments transfer. An horizontal transfer from the upper to the lower areas in the drainage basin, and a vertical transfer of sediments following the infiltration and underground geomorphic networks. Concerning the first direction, it is noticeable to observe the intense soil erosion on the Atlasic flanks and in the lowest silty terraces (the Holocene terrace) along karstic high valleys. The upper Oued El-Atchane for example, in the north-east of Boulemane city, illustrates a case where such terrace is intensely degraded. The seasonal turbid waters of the Guigou river are fed by materials of the terraces destruction. Agradation, sedimentation and pedogenesis are generally observed in the lower sites on different scales. The change in soils forming factors is registered in profiles and traced either in their texture or in their structure and their chemical components.

The vertical direction of transferred sediments is most typical of the karstic domain. Soil swallowing through ponors and fissures is becoming threatening process. The karst depressions are submitted to a vertical soil loss as they allow material transportation when surface waters infiltrate through ponors to the underground systems.

The impressive case of Dayet Chiker (Northern Middle Atlas) in the south of Taza illustrates this problem. Soil loss by erosion and swallowing, activated by the developed underground karst system (the Friouatou cavernous system) is considerably reducing areas of rain fed agriculture of the Bni Warrayn and Ghyata tribes in the

Fig. 6. In the karst domain, the vertical soil erosion following ponors and underground networks is important. In Dayet Chiker, such erosion activates gullies enlargement and tends to generating bad-lands on ponors' vicinities.

polje of Chiker (Fig. 6). Even the reclaimed arable surfaces are important on the polje's borders, the evidence of the land degradation increase is given by gullies enlargement, generating degrading land mass movements on ponors' vicinities. Gullies of 200 to 300 centimetres width and 100 to 200 centimetres depth appeared during the last two decades showing the recent severe trend of soil loss. The phenomenon is accelerated by soil sliding (mainly near ponors), when the mass movement is conditioned by the vertical attraction of the underground karst system. Surprisingly, few farmers try vainly to maintain and conserve soil by continuous obstruction of ponors, as we viewed during our field survey in spring 1998. However the landfill and blocks piling up on the ponors did not stop soil transfer as the involved disturbance was huge and connected to the karst hydrogeology and underground karst. Land degradation is thereby controlled by a hazardous mechanical down transfer of sediments to the caves and developed underground karst forms.

Land degradation on the other hand, may be controlled by chemical processes deteriorating soil fertility. Acidified water issued from rain and surface hydrology is enriched in carbon dioxide from vegetation roots, soil organic matter or bacterial respiration. It becomes a factor of dynamic erosion and crypto-corrosion of limestone while percolating. The solution rate is enhanced and progressive enlargement of karst depressions took place. The resulting clays and soils tend to fill low topographies but further cut-down mobilises soils sink.

Most caves of the Atlas mountains have sedimentary infillings showing surface land use and soil erosion. Generally iron oxides are transported into caves as suspended particles and take the form of red wall coatings, internal alternating concentric thin layers within speleothems and clay or sandy layers on caves' bottoms. Land clearing, farming and poor forestery management have had direct effects on soil erosion - deposition in caves where red infilling materials could be more or less significant indicators of settlement and human factors.

4.2. *The hydrologic indicators*

The hydrologic indicators of desertification and environmental vulnerability are complex indicators (Sharma, 1998). They combine the surface water (runoff, infiltration, evaporation, turbidity changes in water flow, sediment load etc...), the ground water (sequential changes in depth to water and water quality) and the human use of the resource.

The modern agriculture that progressively developed in several points of the Atlas affects most of these indicators. It is a highly water consumer because it is not generally adequate without irrigation. As mentioned above, most farms are irrigated either by derived waters from springs, rivers or even pumped waters from wells lowering progressively the underground water table. Such a problem is seasonally emerging in several regions as in the Guigou basin and the Amekla plateau in the Middle Atlas, where wells excavation is intensively becoming spectacular. The results of a research program we have developed in the Guigou Basin (AI-1005/95), show an important discharge decrease from the upper parts to the lower parts of the basin. The explaining factor is the agriculture use of water. In June 1998, the measured discharge in Foum Kheneg (south-east of Timahdit) was 386 litres per second (the input discharge to Guigou depression). It became 517 l/s at Titzil springs and have been entirely consumed in agriculture through the basin. No water flow have been observed in its lower parts (at Aït Khebbach hydrologic station). Comparatively, the measuring campaign of the October 1997 shows that in absence of the agriculture activities, a general discharge increase have been observed as the input discharge was 329 l/s in Foum Kheneg, 522 l/s at Titzil and 543 l/s at Aït Khebbach hydrologic station. Agriculture's effect water flow is, therefore, evident in spring.

The coincidence of climatic variability, droughts and human overpressure on the resource generates sudden draw-down of the piezometric level affecting the discharge of springs and even the level of karstic lakes (Fig. 7). The Dayet Aoua lake

Fig. 7. Dayet Ifrah. The recurrent droughts and water use affect the lake level. The consequent temporal lake retreat provides fertile soils for intensive agriculture.

(Imouzzer) dryness in 1995 illustrates such catastrophic event. It is in fact a rare event as it is unique in the history of the lake during the century. Most springs feeded by the Atlas aquifers were also affected. Some of them dried before announcing the crisis in perspective. Aïn Chgag spring on the "Dir" for example dried up since 1985 and several indicators of a sustained hydrology have been preserved along its valley. A series of built equipment such as non functional water mills, water dykes (used to keep back water and prevent flooding), traditional irrigation channels (séguias) are indicators of the intense socio-economic activity which took place in the Aïn Chgag valley before 1985.

Under the Mediterranean climatic conditions, springs discharge variability in the karstic system may be attributed to the physical conditions as aquifers recharge follows rain falls and snow melting. However, water use for agriculture on the plateaux and the domestic needs should be considered because they affect the magnitude and the frequency of the hydrologic fluctuations.

The karstic hydrologic system is also complex because the underground reservoirs are not linear, nor regular. They follow the underground cavernous network of conduits, joints and fractures. As soil erosion is progressively active on the surface as evoked above, the transferred soils and sediments from the surface to the underground conduits network may cause their sudden obstruction locally. Consequently a sudden dryness of its connected springs occurs, hence frightening the human communities they feed. Such explaining model has been adopted to understand the Ribaa and Aïn El Atrous springs' sudden dryness in June 1981 (El Faskaoui, 1994).

Finally, the agriculture impacts on karst systems equilibrium is reflected in water quality facets. It is obvious that modern agriculture focus on productivity is based on chemical nutrients and pesticides. No apprehension has been issued for the phenomenon; but seemingly chemical degradation, sewage and fertilisation are locally potential problems of the karstic areas in the very near future.

4.3. *Deforestation, quarries and karst-systems equilibrium*

The Atlas highlands vegetation has been the main forest of the country. It is composed of diverse species (Cedar, Oak, *Quercus ilex*, etc...) and supports populations' life in the past. For many years, it was widely assumed that the forests never fall below an optimal level and their exploitation has grown continually for multiple purposes.

The Atlasic forests were used as summer pasture lands since several centuries. They have been the source of winter fodder for cattle. Fires, heating wood collection, charcoal making and building activities contributed also to forests degradation.

Consequently, the vegetation and its environmental equilibrium have been altered in several sites. An advanced stage of cedar degradation has been observed in the Jbel Habri and Timahdite areas (regions of Ifrane and Azrou). Even the government's program of plantation (the National Program of Reforestation), planting efforts are still unable to re-establish lost equilibrium in most areas.

The continuing growth of urban centres in the Atlas and its surrounding areas creates additional needs of lands and earth materials. The Atlasic substrates, especially the limestone and dolomite formations interested by tectonic activity are convenient for gravel mining to manufacture concrete and building materials.

In the vicinity of Sefrou city for example, the number of operational quarries exceeds presently 15, notably in the Oued Aggay drainage basin and on the Sefrou - Bhalil transect.

Quarrels expansion is becoming a considerable phenomenon and even locally a hazardous factor in terms of environmental equilibrium. In addition to the frequent atmospheric dusts coming from rock crushing, the quarries are becoming factors of deforestation and soil erosion agents, and landscape changing factors. As soon as the extraction ceases, the artificial depressions, generally left without any maintenance, become sites of waste deposition and consequently vulnerable sites of chemical contamination. Within this context, the natural environmental equilibrium and vegetation are in progressive transformation.

A strong conversion of forest areas to mattorals is observed on forest limits. The resulting mattorals are in turn degraded and submitted to reclamation for agriculture. The vegetation, forming a basis of natural defence of soils against erosion, therefore, disappears and phenomenal gully erosion becomes intensive.

4.4. *Some geomorphic indicators*

1. Alluvial deposits of anthropic origin: "alluvionnement anthropiquè"

The alluvial deposits are settled out when the speed of water flow is no longer sufficient to carry them. Their fundamental cause could be physical or anthropic. In the last case they could be named human-induced alluvial deposits as they are attributed to the human action either in their source (origin) or at their sedimentary environment. Two types of human-induced alluvial deposits were recognised. The deposits coming from slopes' erosion as a result of land overuse and deforestation and those spreading through farms, irrigation channels (named seguia or tagua in the local dialect) and river tributaries due to artificial drainage and modern management. They are called anthropogenic as the human action is their initial forming factor. They are transported by running water from slopes and upper parts and accumulate over managed surfaces, terraces, irrigation channels and farms. They occasionally contribute to soil fertilisation when enriched in organic matter but in most cases they are rather negative in their effects. They damage irrigation substructure, equipment and agriculture land. Such negative effects are observed in the Guigou basin (Middle Atlas) for example (Akdim et al., 1998).

2. Badlands genesis in the Middle Atlas large basins

The bad-land landforms are not directly linked to the karstic processes as their genesis is mainly controlled by the surface runoff of sufficient magnitude and duration, the substrates features, and the topographic conditions. However, their recent occurrence on a large spatial scale through the Middle Atlas evokes the question of their evolution within a present-day changing environment.

The cleared forest and mattoral resulted from land reclamation for agriculture, overgrazing by nomadic sheep and goat herds is generally an area of occurrence of rill channels and great erosion rates following rainy seasons. Human removal of natural vegetation reduces the resistance of soils to erosion and consequently reinforce the dynamics of bad-lands genesis, as observed in the Middle Atlas. In the Guigou basin for example, a spectacular bad-land is forming in the fan of Oued El Maleh and its abandoned thalweg, where several geomorphic agents act on rill erosion, material removal and deposition. The artificial canal built near the village of Aït Saïd attracted water drainage on its sides. The vertical erosion of its multiple tributaries contributes to the bad land formation along the canal.

In the Skoura depression, such a change has been fundamental. In connection with the Skoura - Mdez management project failure evoked above, bad-lands are presently forming as natural equilibrium has been disturbed by deforestation and soil erosion.

The soft impermeable substrates exposed to rapid fluvial erosion is a favourable conditions of badlands formation (Campbell, 1989). As soon as the vegetal cover was eliminated, the marly substrates in Skoura depression have been exposed soil erosion. The erosion processes are, therefore, a direct natural response to the man-created deforestation.

These processes have been assessed on the basis of their nature, their location and their magnitude. The operating degradation in Skoura depression is complex. Its most important process is the seasonal sheet floods, which gradually shifts to rill erosion as incision develop. The concentration of water drainage activated rill erosion and gullies formation. The deflation is seemingly an active process in the presence of susceptible substrates, deforestation and wind velocity. No quantitative data is obtained on the aeolean process, but we observed a frequent dust-raising activity in the area, during dry periods. We assume that wind erosion, clearly contributes to particles' transfer and combine its effects to explain the geomorphic landscape genesis and evolution.

5. Conclusion

Population growth and economic factors are argued to be the dynamic factors of landscape change, and are considered decisive and causal variables of land use intensification and land reclamation in the karst domain of the Moroccan Atlas.

The karstic areas in the Atlas mountains are progressively exploited and intensively used but the equilibrium and environmental thresholds are reached and seemingly threatened in many subregions, considering their hydrologic and resources' shortage. The production capacity may be in a cascading loss whenever such thresholds are overpassed and the consequent degradation could be non reversible.

The social stakes are potential factors of environmental disequilibrium in the mountains and karst areas. They should be managed to insure optimal conditions for local development, land use, resources exploitation and environment.

At the present stage of our research efforts, land degradation and karst changing landscapes are apprehended basing on general assumptions and field observations. This provides an initial assessment. Even we note that a more detailed and systematic research is needed to find clear indicators, measure processes and develop estimation methods.

Considering recent environmental changes in the Atlas mountains, it is paramount to parallel the present day rural development and a sufficient reflection on the mountains' future status in a national framework. The mountains' latent capacities and natural constraints should be addressed to outline the limits and opportunities of the sought sustainable development.

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