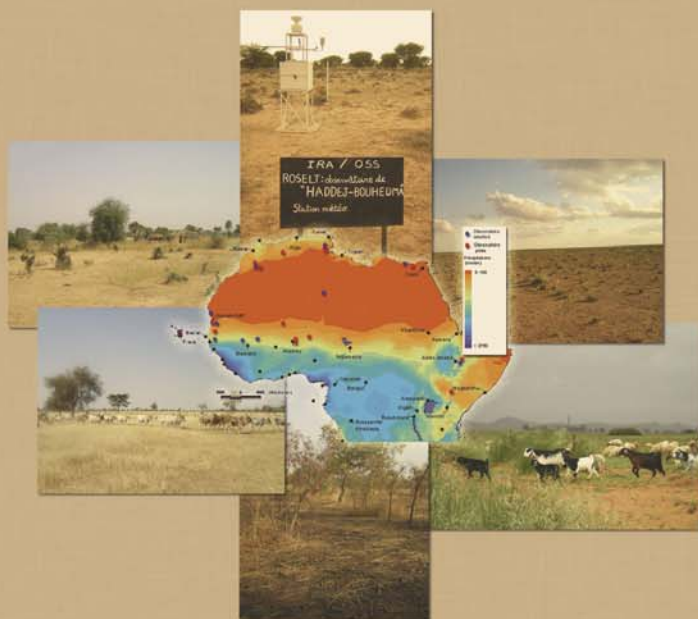


LONG-TERM ENVIRONMENTAL MONITORING IN A CIRCUM-SAHARAN NETWORK: THE ROSELT/OSS EXPERIENCE



Synthesis Collection

No. 3

**LONG-TERM ENVIRONMENTAL
MONITORING IN A CIRCUM-SAHARAN
NETWORK: THE ROSELT/OSS EXPERIENCE**

Tunis, 2008

Synthesis Collection

- No. 1 The North-Western Sahara Aquifer System: joint management of a trans-border water basin
- No. 2 Iullemeden Aquifer System (Mali, Niger, Nigeria): concerted management of shared water resources of a sahelian transboundary aquifer
- No. 3 Long-Term Environmental Monitoring in a Circum-Saharan Network: the ROSELT/OSS experience

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● ● ● **CONTENT**

INTRODUCTION	7
Characteristics of the Observatories	11
1- General information	11
2- Observatories of North Africa	15
3- The Observatories of West Africa.....	21
SUMMARY AND DISCUSSION.....	27
1- Long-term monitoring: monitored approaches and parameters.....	27
2- Main ecological and socio-economic trends in North Africa and in West Africa	29
3- Data management and Decision-Support Products (DSP)	50
4- Scientific achievements	59
5- Orientations and prospects.....	66
BIBLIOGRAPHY	73
ANNEXES	85
ROSELT/OSS NETWORK PARTNERS.....	95

●●● INTRODUCTION

The Long-Term Ecological Surveillance Observatories Network (ROSELT/OSS) of the Sahara and Sahel Observatory (OSS) provides a set of tools which have been developed with a view to bringing together countries where desertification is a major concern requiring a synergy-oriented mobilisation of technical and scientific potential and know-how. The aim is to tackle desertification and apprehend its mechanisms. The definition retained for the purpose of the present synthesis is that of the United Nations Convention to Combat Desertification (UNCCD) which considers desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities".

The ecosystems and the agro-systems of the arid circum-Saharan zone are among the most threatened in the world—which explains the high priority given to Africa by the United Nations Convention to Combat Desertification (UNCCD). The constraints faced by these systems are both natural and anthropogenic. Manifestations of the natural constraints include aridity and climate variability, whereas human-induced constraints include outdated and unsustainable natural resource management practices, all in a rather hostile socio-economic context marked by population growth and rising demand. These constraints and others create new ecological, social and economic conditions for which the traditional modes of natural resource management are ill-fitted and increasingly ineffective. In the debate and controversy surrounding desertification, there is almost a general consensus on one fact: a real decline in natural resources which threatens the production bases and the reproducibility of ecosystems and agro-systems. Several measures aimed at achieving agro-pastoral development on these systems have failed for a variety of reasons including the lack of environmental knowledge

and of the technical and theoretical foundation required to guide the management and the rehabilitation of these systems.

The ROSELT/OSS network has been conceived as a set of environmental surveillance tools spanning several decades with a view to detecting change, assessing its nature and extent, and analysing the mechanisms and effects of natural resource degradation. ROSELT/OSS subsequently provides the relevant biophysical and socio-economic indicators along with diagnostic and decision-support tools. In this vein, ROSELT/OSS works as an interdisciplinary platform which facilitates experience-sharing by promoting and harmonising concepts and methods for data collection, processing, management and analysis. The ROSELT/OSS network also intends to provide an innovative approach with new work methods, including collaboration between research teams, and the dissemination of knowledge and findings. The ultimate goal is to combat desertification as a multidisciplinary and transboundary environmental issue.

The ROSELT/OSS network works with relevant international organisations and programmes, and aims to contribute to the implementation of the United Nations Convention to Combat Desertification mainly through the National Action Plans (NAPs) and the Sub regional Action Plans (SRAPs). ROSELT/OSS outputs are developed so as to provide decision makers and the various development players and stakeholders with information on the state of the environment and key indicators allowing the identification and the interpretation of the risks—in terms of time and space— pertaining to desertification.

Since its inception in 1992, the Sahara and Sahel Observatory (OSS) has placed the set up of the ROSELT/OSS network at the heart of its programmes. Around 15 observatories or clusters of observatories were proposed by the countries located in the OSS zone of action. The observatories concerned by the present synthesis have gone through various phases summarised as follows:

- The labelling phase in 1994. Following an evaluation process, the observatories were recognised as territories of scientific, environmental and socio-economic relevance in accordance with the priorities and objectives of ROSELT/OSS and OSS;
- Selection of pilot observatories (El-Omayed in Egypt, Haddej-Bou-Hedma in Tunisia, and Oued Mird in Morocco) for the first phase aimed at implementing
- ROSELT/OSS recommendations including the finalisation of the monograph (1996- 1997);

- The three observatories thus selected became operational in 1998;
- In 2001, a scientific consortium composed of INSAH, CIRAD and IRD

was created, and IRD became the regional operator. Subsequently, new observatories became operational for a phase ending in 2005. These observatories were:

- Menzel-Habib (Tunisia), Steppes des Hautes plaines du Sud oranais (Algeria),
- Issougui (Morocco), Nouakchott (Mauritania), Ribeira Seca (Cape Verde),
- Bourem-Bamba (Mali), and Torodi-Tondikandia-Dantiantou (Niger) and Ferlo (Senegal).

Desertification is the fundamental issue being addressed at all these observatories. Its manifestations, however, may vary according to local characteristics, practices, or site-specific recent or current socio-economic changes, including recurrent droughts, settlement of communities, and growing pressure on rangelands and agro-systems. The complex interactions of all these factors create long-term trends that are yet to be fully apprehended.

The present document aims to:

- assess the achievements of the various observatories including the results of the surveillance activities and the valorisation of the data and knowledge acquired;
- highlight the trends emerging from the biophysical and socio-economic monitoring, and identify decision-support tools;
- provide a synthesis of the observatories' activities in the light of what has been achieved with a view to providing guidelines aimed at underpinning and strengthening the ROSELT/OSS network.

●●● CHARACTERISTICS OF THE OBSERVATORIES

This chapter describes the background of the observatories and their main ecological and socio-economic characteristics. For detailed description of the observatories see Annexes 1 and 2.

1- General information

The list of observatories and their characteristics in relation to size, main systems and uses are illustrated in Table 1.

Country	Observatory	Land area (103ha)	Dominant ecosystems	Main uses
Algeria	Steppes des hautes plaines du Sud oranais	400.0	Steppe and agrosystems	Cereal cropping, pastoralism
Egypt	El Omayed	100.0	Steppe and agrosystems	Arboriculture, cereal cropping, pastoralism
Morocco	Oued Mird and Issougui	600.0 123.0	Steppe and woodland savanna, agrosystems	Cereal cropping, market gardens, pastoralism
Tunisia	Haddej-Bou Hedma Menzel Habib	16.5 190.0	Steppe and woodland savanna, agrosystems	Cereal cropping, market gardens, pastoralism
Cape Verde	Ribeira Seca	22.0	Agroforestry systems	Rainfed and irrigated crops
Mali	Cercle de Bourem: Bamba test zone	50.0	Shrub savanna and Sahelian agrosystems	Pastoral systems, recession crops, irrigated crops, fishery
Mauritania	Nouakchott*	40.0	Degraded peri-urban ecosystems	Coastal ecosystems; pastoral systems
Niger	Torodi - Tondikandia - Dantiandou	69.8 - 40.0 486	Woodland savanna and Sahelian agrosystems	Rainfed and irrigated crops, pastoral systems
Senegal	Ferlo	2600.0	Woodland savanna and Sahelian agrosystems	Rainfed crops, pastoral systems

* treated partly or not at all in this document.

Table 1. Main characteristics of observatories: land area, ecosystems and main uses

With regard to climate, the common denominator for the observatories is aridity, represented by an annual rainfall interval (P) of between 110 mm in Ouarzazate and 550 mm in Niamey (Fig. 1). The aridity can be distinguished into two zones: Semi-arid with rainfall between 400 and 600 mm or the P/ETP aridity index of 0.20 to 0.45; Aridity (s.s.) with P between 100 and 400 mm (P/ETP of 0.05-0.20). For the rainfall regime related to the Sahara, a distinction is made between observatories with Mediterranean regime in the north and the tropical regime to the south of the Sahel.

According to the Emberger classification, observatories with Mediterranean regime are classified mostly in the arid climatic Mediterranean stage. The semi-arid climatic Mediterranean stage seems exceptional and applies to areas with reliefs, e.g. the El Bayadh station in Algeria. The elevation of about 1300 m is more important than latitude. The difference in altitude largely explains the difference in temperatures; low temperatures (e.g. mean minimum "m" for coldest month) can offset the low precipitation rates in the climagram. The striking difference between these observatories is explained by annual precipitation ranging from less than 100 mm in Oued Mird observatory to more than 300 mm in the Sud-Oranais stations. The inter-season rainfall distribution is bimodal in the western Mediterranean region and unimodal in the eastern Mediterranean region, e.g. the Alexandria station.

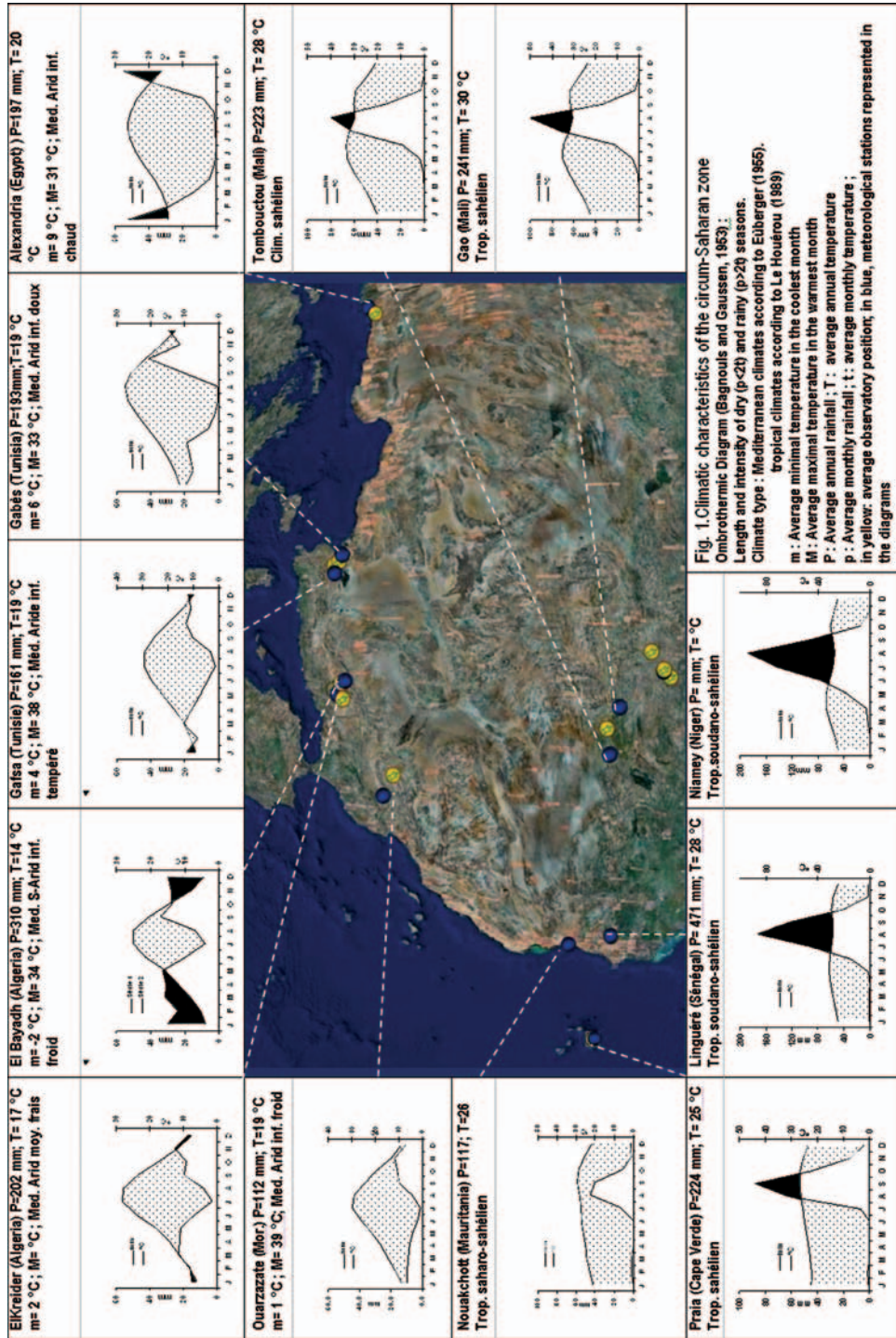
Observatories with tropical regime represent a wide range of climates. The tropical Sahelian climates extends from the Saharo-Sahelian transition (Nouakchott) to the Soudano-Sahelian transition with observatories in the Ferlo (Senegal) and around Niamey (Torodi-Dantiandou-Tondikandia, Niger). The observatories in Ribeira Seca (Cape Verde), and Bamba-Bourem (Mali) are located in the Sahelian climate s.s. Rainfall distribution is unimodal, with the wet season lasting between two to four months and peak season occurring in the month of August.

The arid, Mediterranean and tropical climates are marked by considerable interannual variability, inversely proportionate to the amount of precipitation. The interannual variation coefficient for mean annual precipitation, P, is about 30-60% for all the observatories, but with greater variability in bimodal rainfall patterns.

Major variability in rainfall causes interannual isohyets to oscillate over vast areas thus only providing indicative values for these areas and the climatic sub-zones they delineate. For Hiernaux and Le Houérou (2006), the contours nonetheless constitute a bio-climatic expression, illustrated by a certain concordance with the distribution of certain plant species. The 600 mm isohyet in the intertropical zone marks the northern boundary of many Soudanian savanna species. On the other

end, the 100 mm isohyet corresponds to the southern boundary for perennial species such as *Stipagrostis pungens*, *Retama raetam* and *Ziziphus lotus*, which grow in both the Sahara and in the arid Mediterranean steppe. For Le Houérou (1995), rainfall variability explains the boundaries of certain vegetation, e.g. the succession from forest vegetation to steppe vegetation in northern Sahara.

Greater climate variability limits certain crop production and makes crops more unpredictable. Despite analogous precipitation levels, for instance, certain rainfed crops can be grown more steadily in the Sahel and the Middle East than in the Maghreb where precipitation rates are more variable.



2- Observatories of North Africa

The North Saharan observatories represent three major geographic types of the arid zone. The vastest region is composed of the "plains", both the Hautes Plaines in Algeria (Sud-Oranais observatory) and the southern Basses Plaines in Tunisia (Haddej-Bou-Hedma and Menzel Habib observatories). The second corresponds to the systems of the piedmonts, mountains and hills in the Atlas chain (Oued Mird and Issougui observatories). The third covers the arid coastal environment such as the coastal fringe running from Jeffara in Tunisia to Marmarica in Egypt, represented by the El Omayed observatory.

The climate is arid Mediterranean with precipitation occurring during the coldest seasons, autumn to spring. It is slight, irregular, and can either follow a uni- or bimodal regime. Besides problems of aridity and variable climate, when the rains come, they come crashing down and it usually pours. This subregional climate is marked by hot, dry summers, of varying duration depending on the degree of aridity, sometimes accompanied by dry winds from the south. Most of the biological traits of the vegetation and fauna have been determined by this dryness. Drought, water deficits (compared to "normal"), that can last anywhere from one season to several years, have to be considered in addition to the aridity. During the years following 2000, the North Saharan observatories were affected by a 2-3 year rainfall deficit.

The observatories in Algeria and Morocco display certain continental characteristics with major temperature changes, some too low to sustain certain farm crops. The seaboard and the low altitude of observatories in Tunisia and Egypt make the weather more clement and increase the relative air humidity.

In these two oro-topographic and geomorphologic groups, a distinction has to be made between the edaphic qualities of the glacis with crusted skeletal soils, often inherited from the ancient quaternary, and the more or less low-lying depressions with deep soils dating to the middle to late quaternary.

2.1- Haddej-Bou Hedma Observatory (Tunisia)

The ROSELT/OSS Haddej-Bou-Hedma observatory is located in the Basses Plaines Méridionales (lower southern plains) of Tunisia (Le Houérou, 1959). It covers 75,000 ha and includes the Haddej-Bou Hedma Park and the MAB/UNESCO biosphere reserve named Bou Hedma. The presence of a relictual *Acacia raddiana* tree species, threatened with extinction, largely contributed to the labelling of this observatory in the ROSELT/OSS network. More extensive spontaneous indigenous vegetation, with *Acacia raddiana*

forming a tall shrubby wooded area (Boudy, 1950; Le Houérou 1959 and 1969, Le Floch and Grouzis, 2003), is now only found in the piedmonts south of Bou Hedma and in Bled Talah (Talah is the local name for *Acacia raddiana*). Further, man-induced change has caused transformed the vegetation to make way for steppe, that are more degraded perennial grasses and chameophytes.

The climate in the observatory varies from arid inferior stage with mild winters (according to Emberger), i.e. mean precipitation of 180 mm/yr and mean temperatures (minimum coldest month) of $m = 3.9^{\circ}\text{C}$ and (maximum hottest month) of $M = 37^{\circ}\text{C}$.

The dominant relief is glakis covered with skeletal soils, silty in texture with little organic matter (<1%). On the lowest plains, soils are silt-laden or even silty-clayey. A surface layer, sandy in texture, may exist as the result of a recent æolian deposit. Relics of steppe with *Rhanterium suaveolens* on deep sandy soils may also exist. This is sierozem, whose sandy layers, more or less removed through erosion, allow underlying silty soils to surface in places, often with a thinly sealed surface.

The local population (est. 15,000 inhab., 80% in the rural area) is distributed throughout some 30 douars that make up the family groups. Tree and cereal crops are grown on scattered plots. Plots are allocated in a manner that provides all the farmers in the area with access to water, rangelands and jessour, (an ingenious hydraulic erosion control system used in olive and almond tree production). Wheat and barley are the main annual crops. Irrigated farming was recently introduced and is used mainly for pea and broad bean crops. Sheep farming is important in the steppic rangelands within the observatory's territory. Sheep are often reared alongside agricultural activities to diversify the income sources. In addition, other activities such as artisan crafts and services can also generate income. On the other hand, substantial quantities of wood are still being harvested for household use, despite the introduction of butane gas and new regulations.

2.2- Menzel Habib Observatory (Tunisia)

The Menzel Habib Observatory covers about 100,000 ha and is located in the Basses Plaines Méridionales between $34^{\circ}00'$ and $34^{\circ}20'$ lat. North and $9^{\circ}15'$ and $9^{\circ}58'$ long. East. The Menzel Habib is a rural delegation of the Gabès governorat. In 1994, it had a population of 11,700 consisting of 1,818 households. Monitoring activities through ROSELT/OSS were carried out from 2003-2004.

In relation to climate, this observatory is part of the lower arid Mediterranean stage with mild winters and mean annual rainfall of about 150 mm. Besides its

sparse rainfall distribution, other limitations are imposed by lack of water and soil resources since the soils suffer from low fertility and erosion. The main plant formations represented by the steppe are dominated by *Rhanterium suaveolens* on sandy soils, *Arthrophytum scoparium* on sandy-silty soils, *Artemisia campestris* or *Haplophytum vermiculare* in post-cropping form that replace the *Artemisia herba-alba* steppe with *Gymnocarpus decander* and *Atractylis serratuloides* are dominant on crusted soils.

From the socio-economic perspective, the last four decades have been marked by major changes that have seriously altered the state of environment, the relations between the local populations and the environment, uses, practices, life styles and the adaptation of the local populations to ever-changing environmental conditions. Population growth, sedentarisation of livestock producers, land privatisation, economic liberalisation and agricultural "modernisation" interact as part of the ecological and socio-economic dynamics.

2.3- Observatory of the Hautes Plaines du Sud Oranais (Algeria)

It is located in the steppe western part of the Hautes Plaines covering over 1,548,000 ha located in 12 municipalities (communes). Data are collected at the municipal level in three districts: El Biodh (1,079,000 ha), Rogassa and Bordj El May (773 000 ha). These three municipalities, like the rest of the steppe in Sud Oranais, are characterised by rapid population growth and urbanisation: In 1988, 63% of the population lived in residential groups (Algerian nat. stat. off.). The main activity is still sheep farming, which contributes about 80% of the local economic earnings although agriculture is gaining ground.

The climate is generally dry with mean precipitation between 200 to 250 mm/yr at an altitude of between 1000 and 1100 m.

The main relief is the glaxis, more or less eroded, flat land from the Quaternary period. The other models are the djebels, the depressions (chott, mekmen and daya), the wadis and various sand accumulations.

On the glaxis, the main soil types are calcimagnesian ranging from rendzines to brown calcareous and iso-humic soils (sierozems) that are low in organic matter (generally under 2%). These soils are dominant, but there are also some coarse mineral soils on the slopes and dunes, little evolved colluvial and alluvial soils and halomorphic soils located in the chotts and mekmens.

The description of the pilot sites focus on observation stations that represent the types of steppe, constraints and perturbations to land. When they were

established, the three steppe stations represented the three main physiognomic facies (Table 1) of the three main species: sparta (*Lygeum spartum*), alfa (*Stipa tenacissima*) and sagebush (*Artemisia herba-alba*)

Only 25% of the working population (1998 figures) is engaged in pastoral livestock production as compared to 75% in 1966. Nearly all efforts to make this activity more attractive have failed. The sheep-rearing sector constituting approximately 80% of the national flocks live in the steppe is going through countless problems due to resource degradation and the structural droughts that are recurrent in these regions.

2.4- Oued Mird Observatory (Morocco)

The Oued Mird ROSELT/OSS Observatory is located in Ouarzazate province. It covers a land area of 60,000 ha; and is nationally known as SIBE (Site d'Intérêt Biologique et Écologique). To make it more representative from an ecological and socio-economic point the observatory has been expanded beyond the boundaries of the SIBE to include two douars. Each douar is a functional unit managed according to rules established in Aït Isfoul.

The Oued Mird Observatory is located in a hyper-arid climate with cool winters and a mean annual precipitation of 71 mm/yr (Zagora station). The observatory lands form a transition between the Kem Kem plateau and the hilltops of Jebel Bani in the Anti-Atlas. It covers a great part of the Oued Mird catchment basin, which stretches over 1260 km² at an elevation of between 637 and 1230 m including valley consisting of six quaternary terraces.

The sandstone and quartzite in the geological substratum explains the sandiness of the soil. Depending on the geomorphologic situation, the area is either covered with coarse mineral soils or less evolved soils formed from alluvium that sometimes overlay older soils. Although there are some exceptions, most soils contain little organic matter (<0.5 %). In addition, two-thirds of the land are dominated by scattered steppe with *Farsetia hamiltonii* and *Fagonia zilloides* while the remaining one-third of the area is home to *Acacia raddiana* interspersed with low woody plants and herbaceous growth.

Crops are either rainfed or irrigated with water from wells (188 in 2004) classified as collective dug wells (drawdown assumed to be negligible), unequipped wells (zero drawdown) and equipped wells (drawdown possible by pumping, maximum 2 hr/day).

Landscape diversity has not been fully evaluated according to the ROSELT/OSS Methodology Guide, but the main types of habitats in the Oued Mird observatory can be divided into five:

- steep slopes;
- glaciais with low sloping, detritic cover and sparse vegetation (about 5% plant cover); mainly pure steppe, structured by small shrubs such *Hammada scoparia*, *Farsetia hamiltonii* and *Gymnocarpus decander* or punctuated by sparse stands of *Acacia raddiana*;
- relatively dense *Acacia raddiana* forests (plant cover 20-30%) that may be on glaciais, the terraces or depressions;
- wadi valleys with *Retama retam*;
- irrigated farming (market gardens and tree crops) mainly in the terraces and extended irrigation areas.

Pastoral livestock production has long been practiced on collective, quite flexibly managed rangelands that belong to the local tribe. Herds can leave the valley if there is not enough forage and similarly, herds from elsewhere are tolerated on these rangelands. With increased sedentarisation, animals are trekked over shorter distances as "sedentarised livestock production", albeit extensive, becomes more popular. At present there are 6,100 head (70% goats, 30% sheep); with the extensive production method on the rangelands is used for less than 30%. Agriculture on irrigable lands is becoming more important throughout the region, mainly to grow food crops even though livestock production is still the economic mainstay.

2.5- Issougui Observatory (Morocco)

The Issougui Observatory covers the territory in the Ouarzazate province belonging to the Aït Zekri tribe that lives in two rural communes: Ighil N'Oumgoun to the north and Skoura to the south. It extends from the Saghro chain to the south via the Ouarzazate depression in the centre to the province of Azillal in the High Atlas to the north. Hydrology: the Skoura and its two effluents, Imdri and Toundout, flow into a water table that irrigates the largest palm tree plantation in the catchment area as well as the orchards between Boumaine and Kélâat Mgouna. Mean annual precipitation ranges from 300 mm in the mountains to 100 mm along the Saghro. The climate varies, between cold semi-arid ($m < 0^{\circ}\text{C}$) at elevations above 1700 m to cool per-arid in the low and middle valleys. The Aït Zekri tribe

(over 7000 inhabitants) is part of the Aït Imeghrane confederation that includes six other tribes. The land is used mainly for transhumant livestock production and agriculture.

2.6- El Omayed Observatory (Egypt)

The El Omayed Observatory (Egypt) is located about 80 km west of Alexandria. It is part of the coastal strip (15 to 30 km wide and 500 km long) and covers a land area of 100,000 ha. The area includes a biosphere reserve (part of the MAB/UNESCO "Man and the Biosphere" programme). Many national and international projects are being implemented on monitoring natural resources and how they are used by man.

This observatory is composed of three morphological groups that are widespread from north to south:

- a strip of land characterised by alternating calcareous ridges and sand depressions;
- an undulating plain traversed by calcareous ridges;
- an inland plateaux covered with stones and sand (æolian sand veil).

The climate is arid: $P = 197$ mm with hot wintry variant ($m = 9^{\circ}\text{C}$) for the Alexandria station.

The vegetation of these land groups ranges from coastal dune formations to hamada desert formations, via saline depressions, rocky ridges, where crops and other anthropogenic vegetation can be found.

Subterranean water resources are composed of relatively shallow, abstractable aquifers and relatively abundant but very saline water tables dating from the Cretaceous to the Miocene period. In the coastal plains, water tables are recharged by heavy rainfall in the dune area that provides good quality water for tree cropping. A water supply line originating in the Nile has recently been added to El Omayed's water resources.

Land is mainly used for extensive livestock production (mostly sheep and goats) and agriculture (an average of 15 ha per family), mainly tree crops, the leading one being fig trees, and to a lesser degree rainfed cereal crops.

3- The Observatories of West Africa

The observatories in the West Africa subregion belong to the Sahel, s.l. an area that includes a transition zone to the Saharan domains in the north and the Soudanian domains in the south. The Sahel is an ecoclimatic and biogeographic entity with arid to semi-arid tropical climate, controlled by the **monsoon** in the Gulf of Guinea and the Saharan dry, hot, trade winds, the harmattan (Hiernaux and Le Houérou, 2006). Geomorphologic models and current polygenic soils are the result of alternating arid and wet tropical pulsations during the Quaternary (Bertrand, 1998), dune systems and eroded lands resulting from arid episodes, deeply weathered rock, leaching, soil acidification, deep migration of ferro-aluminous oxydes, and great diversity of alluvial and lacustral systems as a heritage of the wet periods. Despite a certain homogeneity in the geological substratum, this has led to the formation of diversified soils ranging from sandy to vertisols via silty soils produced from river erosion (Hiernaux and Le Houérou, 2006).

The savanna, also called the steppe, is the dominant vegetation. It is composed essentially of two layers, one forming the grass cover mainly *Poacea* and the other composed of scattered woodlands of varying heights.

Further to the south, the bands of tiger bush or vegetation arcs (*Brousse tigrée*) exemplify the Soudano-Sahelian transition vegetation which, north of the 15th parallel, is replaced by arid steppe, and south of the 13th parallel becomes homogeneous. Between these two parallels, the tiger bush appears in many forms: between 13° and 13.5° "marbled" bush (*brousse persillée*) at 13°, "stippled" bush (*brousse mouchetée*) "dotted" bush (*brousse ponctuée*) or rosace shaped (*brousse en rosace*) further to the south (Ambouta, 1997).

The agro-pastoral land are dominated by livestock production, particularly the bovine constituting about 60 million which when expressed as livestock units (LU = animal equivalent to 250 kg) comprises of 57% of the total livestock. The smaller stock, sheep and goats are approximately 170 million, accounting for 32% of the LU while camels accounts for only 8%. Most herds are raised on rangelands (Dicko et al., 2006). On the other hand, agriculture is mainly rainfed but with some irrigation along the water courses.

3.1- Ferlo Observatory (Senegal)

Two of the observatory's subterritories have been studied, one where pastoral activity is dominant (north and central Ferlo) and the other mainly an agricultural zone (south Ferlo). The Ferlo-Nord subterritory has been marked out as a "buffer"

zone, between 5 and 15 km to the following water points: Widou and Tatki boreholes, the Souilène (Keur Mor Ibra) wells. The Ferlo-Sud subterritory covers the Ouarkhokh rural community which includes Linguère that was studied and mapped during the exploratory phase of the ROSELT/OSS programme (1995-2000).

The ROSELT/OSS Ferlo observatory is in the Sahelian climatic domain.

Ferlo-Nord is part of the Sahelian subzone s.s. (P = 200 to 400 mm; Le Houérou, 1989). The monsoon lasts three to four months and receives 90% of the annual precipitation; mean annual precipitation, measured at the Podor station, is 221 mm of which 70% falls in August and September. The hot, dry harmattan lasts for close to nine months a year with mean temperatures of between 22.8°C (January) and 32,9°C (June). Maximum temperatures are recorded in May and June with a slight drop in August.

Ferlo-Sud is in the Soudano-Sahelian transition subzone (Le Houérou, 1989), with a south Sahelian rainfall regime. Precipitation oscillates between 330 and 490 mm and temperatures vary between 24°C (January) and 32 to 35°C (June). The mean rainfall for the 1934-2005 period at the Linguère station was 440 ±50 mm, with a coefficient of variation of 32%, a figure slightly greater than the range described by Le Houérou (1992). The strongest winds are north-east to east are observed between January and July, while the south west to west winds occur during the rainy season and are usually light (Ndione, 2002), south-west to west.

The main ethnic groups are the Wolofs (74%) and the Peulh (26%) with the latter practicing extensive transhumant livestock production. The main economic activity is agriculture represented by 63% of the exploitation unit leaders, then, followed by livestock production (21%), trade and artisanat (8%). In the Ferlo, agricultural activities predicate on seasonal variations in climate. In July, when the dry season ends, early-maturing, drought-resistant varieties such as souna millet, cowpea and groundnut are commonly grown.

The wet season occurs from early August to mid-September, which is a time of active growth, development and flowering. Lower rainfall, around the beginning of October, augurs the return of the dry season, the harmattan winds, high temperatures and a high evaporation rate. This coincides with harvesting and the grass cover dries up and the watering points gradually subside.

3.2- Ribeira Seca Observatory (Cape Verde)

It is located in the catchment area of Ribeira Seca, in the middle of Santiago Island, and starts in Pico de Antonia, at an altitude of 1394 m. The relief of the

observatory lands is uneven, between 200 and 600 m. The climate consists of a wet season from July to October with torrential irregular rains, and a long dry season from November to June. The main environmental constraints are Sahelian type aridity and erosion-prone soils further stressed by tillage.

In a normal period (e.g. 1970-2000), precipitation is between 200 mm in the coastal zone to 600 mm in the highest areas. Spatial variation also depends on the exposure of the slopes to the trade winds (alizés). The mean temperature varies between 20 to 25°C.

The Ribeira Seca observatory belongs to the Santa Cruz municipality. Its catchment area had a population of 19,299 in 2000. The main activities are agriculture, livestock production, trade, fishing and small-scale industry. Economic problems can be traced to the weak production capacity attributed to the shortage of arable land, the traditional land management and inaccessible credit facilities.

In the rural area, most of the families have at least one person who has emigrated but as time goes by, the emigrants often reduce their contribution to the family income.

There are setbacks in practicing rainfed agriculture. More often, priority is given to improving water and soil management within the catchment basin. Population pressure, recurrent droughts and traditional land management in combination, implies expansion of cultivated areas into marginal lands (wooded and/or steeply sloped zones) and gradual elimination of fallowing. Progressive land degradation and desertification further complicate the situation for the rural populations: "a vicious circle in which land degradation feeds poverty and vice versa".

3.3- The Torodi-Dantiandou-Tondikandia cluster of observatories (Niger)

The mean rainfall in this group of observatories ranges from 650 mm in (Torodi) to 400 mm in the Tondikandian canton where the climate is Sahelian. Most problems are connected to man-induced pressure stemming from population growth and, in some cases, increased sedentarisation. Agriculture is taking over more lands (e.g. Banizoumbou-Dantiandou and Tondikandia), and the natural resources, e.g. firewood, are being overexploited, e.g. in Torodi and Tondikandia.

The wet season starts in May and ends in October with about 60% of the rain is recorded in July and August (90% between June and September). The mean annual temperature is 29.8°C; the maximum daily temperature sometimes reaches close to 46°C at the end of the dry seasons. The ETP is around 2,500 mm/yr-1 and only drops below rainfall levels at the peak of the wet season.

The **Torodi** observatory is a Sahelo-Soudanian type located in the wettest zone, receiving approximately 650 mm of rainfall. The **Dantiandou** observatory is close to Niamey where the mean precipitation is 564 mm/yr with semi-arid tropical Sahelian climate. This type of climate is also found in the territory of the **Tondikandia** observatory located northeast of Niamey where the mean annual rainfall is 410 mm.

These observatories are characterised morphologically by alternating plateaus and lowlands. The plateau are usually laterite iron-pan with wooded vegetation, often composed of *Combretaceae* shrub such as *Guiera senegalensis* and *Combretum* sp. The slopes adjacent to the plateau, sometimes called a "watershed" or a "catchment basin" are covered with sand accumulations (sand skirts), which are areas for rainfed crops and fallow. Irrigated crops can also be grown in the valley beds.

In Banizoumbou, which is the main observation site for **Dantiandou**, the most common vegetation is the tiger brush composed of tree and shrub layers with *Combretum* sp., *Guiera senegalensis*, *Acacia ataxacantha*. The herbaceous species include *Zornia glochidiata*, *Aristida adscensionis*. The slopes are often overlain with sands where the vegetation is either herbaceous or trees and shrubs with *Combretaceae* and lianescent acacia based on *Guiera senegalensis* and sometimes *Balanites aegyptiaca* or *Faidherbia albida*. The herbaceous species are dominated by grasses such as *Aristida mutabilis* and *Cenchrus biflorus*. Most soils are tropical ferruginous on slightly clay-leached sand.

In the low-lying areas (koris), the hydromorphic soils are covered with thickets, essentially *Acacia nilotica*, *A. seyal*, and bushes such as *Bergia suffruticosa*, and *Bauhinia rufescens*.

Most of the population in the west of Niger live in the rural areas and belong to four ethnic groups: Haussa, Zarmas, Peuls and Touaregs. The main problem in the Torodi observatory is its high annual population growth (7%) with population density in certain areas above 60 inhab/km². In Dantiandou, the population density is 19 inhab/km² (1994) while at Tondikandia, the estimate is 30 inhab/km².

Land use depends on existing biological resources and soil cultivability. In the Torodi observatory, the northern part of the canton is agro-pastoral (Kobadié unit) while the south is sylvo-agricultural (Torodi unit). The rising population numbers implies more pressure on the soils and on the woody species (firewood).

In Dantiandou, 70% are crop farmers with the remaining 30% both integrating livestock and crops. The rainfed crops include millet, sometimes intercropped with cowpea or sorghum. However, small gardens are cultivated under irrigation along

water points but livestock production is increasingly sedentary or "locally transhumant".

In Tondikandia, besides sylvo-pastoral practices on the plateau and agro-sylvo-pastoral in the low-lying areas, the land is used for mining natron, an evaporative rock. The herders zigzag the area driving their animals on grandes transhumances (distant seasonal migration).

3.4- Bourem Observatory (Mali)

The Bourem observatory stretches between latitudes 16 and 20° north and embraces the Gao, Bourem and Kidal circles with 27 observation and vegetation monitoring sites of which 17 are in the Bamba commune and are considered pilot sites. These sites are located in Haussa territory north of the river.

The ROSELT/OSS Bourem observatory belongs to the Sahelian climate domain, the Saharo-Sahelian transition subzone (P between 100 and 200 mm, Le Houérou, 1989). Mean annual rainfall is 150 mm (Dembelé et al., 2006).

The observation territory includes the Bas Plateau composed of a layer of sandstone or limestone overlain by dunes and alluvial terraces from the Tilemsi region and the Niger River. The Bamba commune (8,000 km²) is part of the Tilemsi valley and is located in the Kounta agro-ecological zone which is composed of three very different units: the regs in the east, the ergs in the north and the west and the alluvial terraces of the Niger River in the south.

The regs are covered with woody vegetation, mainly *Boscia senegalensis* and *Acacia ehrenbergiana* and a herbaceous layer, mainly *Aristida sp.* and *Schoenefeldia gracilis*. The erg includes tree and shrub layers of *Acacia raddiana* and *Leptadenia pyrotechnica* and a herbaceous layer of *Panicum turgidum*. In the valley there are badly degraded stands of *Hyphaene thebaïca*.

The total population is approximately 30,000 inhabitants with a density of 3.75 inhab/km², living in 19 villages. There are 7 ethnic groups, including the Songhaï, Armas, Peulhs, Arabs and Touaregs.

The main socio-economic activity in the area is livestock production. According to the 1996 census, the Bamba arrondissement counted 14,799 head of cattle composed of bovine (2,059), shoats (10,390), donkeys (1,364), horses (71) and camels (915). The weather is so dry that crops must be irrigated and the only arable land is on the floodplains of the river bed of River Niger.

●●● **SUMMARY AND DISCUSSION**

The data collected in the observatories using permanent monitoring tools are the only data available on changes in the state of the environment. Needless to insist on the value of these environmental data that are so often scanty worldwide (Bakker et al., 2002). They are even scarcer or non-existent in the Sahelian and Mediterranean arid environments (Hein, 2006). Assuming that current mutations will continue, i.e. intensified resource exploitation and sedentarisation. These data are and will continue to be crucial to explaining the mechanisms of present and future environmental changes in the areas surrounding the Sahara.

1- Long-term monitoring: monitored approaches and parameters

Two approaches are used in ROSELT/OSS observatories to monitor the environment. The first is designed to monitor biophysical parameters through measurements and evaluations of changes in natural resources: meteorology, vegetation, wildlife, soils, water resources, etc. The second is based on surveys for the regular collection of socio-economic data. These surveys are conducted on a representative sample of the exploitation units (EU) in each observatory.

The data compiled through long-term monitoring is based on the principle of the "minimum information kit" that provides enough variables to measure or study in order to obtain essential information on a system's overall environmental setting for any time and at the appropriate variation scale.

There is a two fold, dynamic objective, organised as part of a network, mainly to obtain information that is comparable in both time and space. The final goal, thus, is to produce standards for sampling, and for interpreting and expressing results.

This gives an idea of the constraints that need to be overcome. The constraints are summarised as follows:

- complexity of interrelations between biotic and abiotic components in the ecosystems, with the need for the extraction of the most relevant indicators through interdisciplinary work;
- levels of knowledge on environmental conditions;
- differences in human skills (teams) and technical resources working on the programme;
- environmental differences between the observatories, linked to the specific characteristics of the biophysical and socio-economic conditions;
- special problems and, hence, priority given to them at the local level.

To harmonise approaches, observatory teams have been invited to special workshops and methodology manuals have been written. These manuals contribute to the definition of a set of biophysical and socio-economic variables.

With regard to biophysical information, attention is being given to:

- land use: essential instructive data, at specific scales, on the state and structure of homogeneous land use units, in relation to geomorphologic types and vegetation, both natural and artificialised (agrosystem);
- state of vegetation by considering the structure, density, biomass, production, phenology, etc., depending on the case;
- edaphic characteristics: soil fertility levels, weathering, etc.;
- hydrological characteristics: quantitative and qualitative inventory of water resources.

For certain observatories and certain variables, a first typology and inventory phase was required to fill knowledge gaps especially for the fauna and soils. Similarly, information on many components of the environment was uneven, in both qualitative and quantitative terms, because of the diversity of ecological situations, technical difficulties and inadequate resources.

However, there were minimal problems with data from surveys. The approach used for the socio-economic variables is based on the "ROSELT/OSS Guide for the Evaluation and Monitoring of Natural Resource Exploitation Practices"

(ROSELT/OSS CT2, 2005). The principle involved a three-tiered by questionnaire survey:

- administrative unit (AU);
- exploitation unit (EU);
- elementary "plot" or "herd" providing detailed information on resource exploitation practices (vegetation, soils, water, etc.)

Certain variables, especially the ones concerning the last level, are complementary to the biophysical data since they provide information, albeit a posteriori, on the causes of environmental weathering and help build up hypotheses that can guide interpretations and future in-depth investigations.

Data from these surveys have already been used in Local Environmental Information Systems (LEIS) and in making the first models of the socio-economic functioning of territories in the observatories.

The list of variables that are being (or should be) monitored is given in the table appendix in this document or in ROSELT/OSS technical documents (ROSELT/OSS DS1, DS2, DS3 and DS4, 2004; CT2 2005 and CT1 2007).

2- Main ecological and socio-economic trends in North Africa and in West Africa

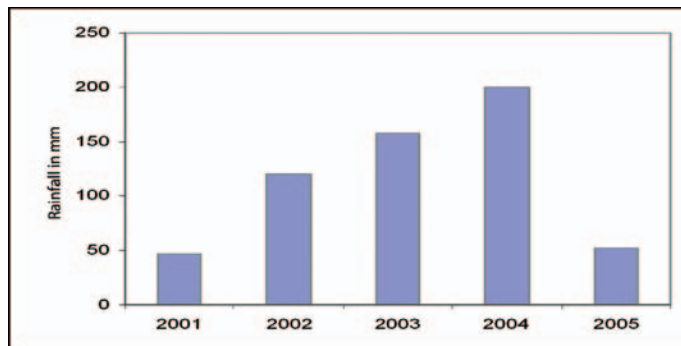
It takes many years for long-term monitoring, as the name implies, to be able to confirm profound changes to the ecosystems, especially when the system is prone to major variability. This explains the main objective that was established at the beginning of observatory operations, namely, to compile enough existing historical data from earlier work over a long enough period of time and, whenever possible, bring out the most important emerging trends.

2.1- Climate trends

In most of the observatories, climate, especially rainfall which is a key element, shows great inter-annual variation:

- In the Haddej-Bou Hedma observatory (Tunisia), between 1994 and 2005, rainfall amounts from (September to August) showed 6 years of deficit ($P < 80\%$ of mean), 2 normal years and 3 surplus years ($P > 110\%$ of mean) particularly the year 2000, 2004 were the only surplus years (Figure 2).

Figure 2: Annual rainfall (Sept-Aug) in Haddej-Bou Hedma



This evolution was much the same in Menzel Habib, the neighbouring observatory. The Oued Mird stands out because of the severe rainfall deficit between 1999 and 2003 when the mean rainfall was 34 mm/yr, a deviation from the mean of 69 mm/yr-1 for the 1984-2003 period (Zagora station); the same phenomenon was observed in the neighbouring stations and in the Issougui observatory. Recordings in the observatory's station confirm this evolution and indicate a rainfall surplus in 2004 followed by a relatively dry season (beginning of the 2004-05 period). A similar scenario was noted in Sud-Oranais. For 7 years (1997 to 2003), the mean rainfall was 185 mm/yr was notably below the long-term mean (190 mm/yr). The deficit was more than one-third (36%). As in the above mentioned observatories, 2004 was a surplus year, but 2005 was relatively dry.

Data on the West African observatories indicate that rainfall figures for recent years have been below long-term averages. For the São Jorge (Cape Verde) station, the mean annual figure for the 1988 to 1997 period was 335 mm/yr as against a mean of 449 mm over a 40 year period. According to the Niamey station, drought also seems to be a tendency in Niger.

In the Ferlo (Linguère), since 1969 there have only been 11 years with above normal rainfall ("normal", based on 1961-1990 records, is 401 mm/yr). In between the normal years (1931-1960 and 1961-1990), the rainfall deficit has been 129 mm. Last, between 1994 and 2005 mean rainfall has been 390 mm while the long-term from 1934 to 2005 (72 years) mean was 440 mm (Figure 3).

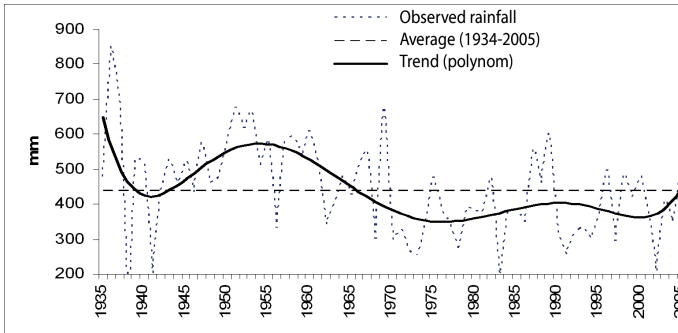


Figure 3: Annual rainfall (Linguère station, Ferlo observatory, Senegal)

Drought spells are common to nearly all the observatories although they are apparently more chronic in the Sahel, and monitoring records show that the trend has become more severe in the North African part of the network during the recent years. Without pre-empting the significance of this trend for the future (cf. *infra*), these drought records bring out the singular character of this situation during the first years of ROSELT/OSS observatory operations.

2.2- Socio-economic trends

Besides aridity and occasional droughts, the ecosystem is also subjected to man-induced pressure, shown clearly by a key indicator such as population growth.

United Nations statistical data on populations shows high overall population growth in Africa. (<http://millenniumindicators.un.org/unsd/default.htm>). Between 2000 and 2005, the annual population growth rate was 2.20% for Africa as a whole while the world figure was 1.2%. The rate in North Africa (1.90%) was lower than in West Africa (2.60%). Between 1950 and 2000, the population more than tripled in North Africa (3.30%) and in West Africa (3.80%). There are local variations of course. In North Africa, for instance, the rate is highest in Libya (1.96%) and Egypt (1.91%) and lowest in Tunisia (1.10%). In West Africa, the rate is 3.39% in Niger and 2.35% in Cape Verde, respectively the highest and the lowest figure in the West African part of the OSS zone. However, there are local variations of these rates depending on the scale. For example, the rate is 1.80% in the Ferlo observatory compared to 2.70% for Senegal as a whole.

The consequence of growth in human population goes hand in hand with simultaneously increase in people's needs, hence negative repercussions on the environment through overexploitation, mainly using traditional methods, to meet the demand, especially on arable lands, pastoral rangelands and firewood.

2.2.1- Trends in land use

In arid circum-Saharan Africa, the land is used mainly for livestock production, agriculture, gathering wood and other natural plants as food and medicine. Several key indicators of change in uses have been brought out in the ROSELT/OSS observatories by analysing and summarising existing and monitored data.

a- Livestock production

Livestock production, be it sheep, goats on the steppe, or cattle in the Sahel, is practiced nearly everywhere in the observatories. Extensive livestock production system is the most common method; which involves moving the animals to more or less distant areas in a more or less organised manner. Animals are trekked in search of grazing land through nomadism, which is presently declining to transhumance.

In the north of the Sahara, the decline and even the total disappearance of nomadism does not seem to have systematically wiped out extensive livestock production, which is still practiced through transhumance. In Menzel Habib, 79% while the remaining land are under communal grazing. In addition, 78% of the farms have their family herds grazed traditionally in the rangelands. Similar practices were noted in the Haddej-Bou Hedma observatory and other observatories but with slight variations.

Presently, there is no standard definition of the term "large livestock producer", it applies to anyone with over 50 heads in Haddej-Bou Hedma and anyone with over 200 head in the Hautes Plaines du Sud Oranais.

Ever-growing population needs has aggravated "rangeland saturation" (De Planhol, 1979), a trend that includes several factors such as resource availability and economic, social and cultural factors.

In the Menzel Habib observatory, shrinking rangelands apparently curtail prospects for pastoral development. This is also the case in the Oued Mird observatory (Morocco) where pastoral activities no longer have a structural role although pastoralism in the area was credited with maintaining and conserving traditional practices the longest.

Livestock production, whether transhumant or near-distant often with feed supplements, has increasingly detrimental effects on the environment and the vegetation. In the Oued Mird observatory, there is a tendency to replace the indigenous sheep other breeds that are better adapted to the environment as well as keeping of cattle. The same is being done in the Sud-Oranais.

The stocking rate is increasing and for the Menzel Habib was 0.75 head/ha, excluding the transhumant herds. This stocking rate does not have any meaning in determining rangeland grazing capacity since feed supplements have been introduced and varies, depending on vegetation status. In the Hautes Plaines du Sud Oranais observatory, supplements cover 62% of the animals' needs. This was an estimate by the observatory staff but is considerably lower than the figure reported by Boutonnet (1989) and by Bourbouze and Lazarev (1991). Feed supplements were not administered as part of a rational management plan but rather to meet a necessity; growing herd sizes and overstocking, especially during the dry season, have degraded the plant canopy thus contributing to the scarcity of natural fodder.

In the Sahel, livestock production is the primary renewable resource. It has also undergone major changes related to droughts that cause time bound disturbances, economic collapse and migrations and accelerated growth in human and animal populations leading to overexploited rangelands, herd migration to less arid zones in the south, transfers of herd ownership; hence structural changes in the livestock and rangeland management (Dicko et al., 2006).

In Ouarkhokh, a rural community in the Ferlo observatory, transhumance is practiced over variable distances ranging from a few km to hundreds of km usually during the dry season. The trend is increasing pressure on the rangelands from migrant herds and the resulting opposition, even conflicts. Stamping, plant snipping, and pollution of ponds used as free watering points for the herds are just some of the harmful consequences.

In the Bourem observatory (Mali), livestock production is also the main activity. It is practiced on communal rangelands, either as far distant transhumance or as quasi-permanent grazing along the river. Transhumant livestock methods here often trigger conflicts on access to water points.

In the Cape Verde observatory, livestock production is secondary and does not display any major trend, and in the Niger observatories, it is still extensive.

Feed supplementation for animals in the Sahel is common practice especially during the dry season when priority is often given to the sheep and goats, e.g. the Ferlo region.

In the observatories as a whole, animals are usually the traditional source of savings since animals "escape various solicitations better than money" (cf. Niger report). Furthermore, in cultural and religious traditions, relatively old sheep are kept as sacrificial animals. But on rangelands where feed supplements are becoming more important than natural fodder, this source of savings is becoming

uncommon due to the cost implication of concentrates used in feed supplementation; keeping many unproductive sheep in the flock is becoming too expensive.

b- Farming the lands

Cereals are grown mainly for home consumption in nearly all the observatories, probably because of the low yields (usually less than 5 q/ha) despite the increase in hectareage under cultivation. This is the case for Haddej-Bou Hedma where 82% of the cereal harvested was for home consumption. The real change in the introduction of tree crops during the last half century as in the observatories of Tunisia; and its gradual and rapid extension in these observatories including El Omayed and, to a lesser extent, Oued Mird. In Haddej-Bou Hedma and Menzel Habib, olive trees and cereal crops have left deep marks on the environment.

Agriculture has been taking over more land mainly to meet the increased needs of a growing population with a higher standard of living.

Throughout the observatories in North Africa, part of the rangelands have been transformed into rainfed and irrigated cropping lands, although some authors expect a decline in agricultural activities and subsequently a drop in yields due soil degradation caused by resource overexploitation and even climate change (Visser, 2001).

Agricultural expansion is not only an answer to increased needs in North Africa, it also leaves room for speculation and income diversification:

- One indicator of this speculation is the use of cereal crops in livestock production. Cereals are one of the main sources of supplementary feed for herds in nearly all the observatories where livestock production is the primary activity, especially in North Africa (Bourbouze, 2000, 2006).
- Cereal cropping in the steppe often makes it possible to take over lands still under communal governance, at least temporarily. Before land privatisation in Tunisia, tree cropping was also a way to ensure more permanent ownership as in the case of Menzel Habib and El Omayed observatories.

In the Sahel, trends in agriculture vary from one observatory to the other.

The arid climate, like in the Bamba site, is not appropriate for rainfed cropping. In this observatory, crops are grown on the flood plains near the river. Land tenure is governed by two traditional systems: either by a village chief if the lands belong to the village as a community (Songhai system) or by the state which nonetheless recognises customary law (Arma system). This report focuses on difficulties that occur with increasing pressure on farm lands triggering conflicts with growing

livestock numbers along the river and when mobile dunes threaten the cropping areas.

The Ribeira site (Cape Verde) gives evidence of problems with crops on slopes where the soils are fragile. The results demonstrate the importance of soil erosion: in one year some 21,000 t/ha of land was displaced. Also, crop type analysed indicate that maize was highly susceptible to all types of erosion, especially after traditional weeding and hoeing, which further enhances soil vulnerability through increased exposure. Measurements also indicate that the land cover rate and the slope play a major role in the erosion process. Erosion is practically negligible in groundnut crops where the plant cover rate is higher (over 20 plants per m²) and when the crop is planted in strips that are perpendicular to the slope.

Intermittent agriculture, which is widespread in the Sahel, is marked by crop rotation and land rest periods called "fallow". This system used to be supported by the low density population and land availability (Ruthenberg, 1980, Delabre, 1998). It served to regenerate the vital attributes and factors of production that the farmers have no control. Because of agricultural expansion, land fallowing is being practiced less and less. In the ROSELT/OSS site at Banizoumbou, Niger, for instance, crops covered 12% of the potentially arable bush before 1950 (Leduc and Loireau, 1997). At this same site, only 35% of the land was fallow at the end of the last century, and the figure had dropped to 10% when the lateritic plateau that cannot be farmed using traditional methods is excluded (Delabre, 1998).

c- Picking activities

The main wild gathering and picking activities focuses on firewood, followed by medicinal plants and food plants for both human and animals. In all the observatories with wooded areas, reports indicate offtake of trees and shrubs for local consumption as firewood and even at times sales.

Large amounts of wood are still being removed for household use, despite the introduction of Liquefied Petroleum Gas (LPG) and new regulations e.g. Haddej-Bou Hedma. Using wood is justified since there is no other source of low cost energy and since this is the custom. Cooking on charcoal is considered more efficient and healthy.

In Oued Mird, removal of timber and firewood from the *Acacia raddiana* stands is thought to threaten the forests. Near the villages, it is done on a large scale with branches being cut and trees felled. In the neighbouring Oued Draa valley, Alifriqui et al. (1995) report that wood is also harvested for other activities including pottery. These authors cite Vignon & Rozis (1993) who evaluated wood consumption at 165 t/yr for a production level of 100 kg/ha/yr.

Reports from the Oued Mird observatory stressed that the eradication of the plantlets and the parasite attacks inhibited the germinating capacity, thus, the reproduction of *Acacia raddiana*. This was reported years ago (1887 and 1889, Grouzis et Le Floc'h, 2003), at other sites such as Bled Talah (Haddej-Bou Hedma observatory).

The phenomenon is the most pronounced in the Sahelian observatories. Grazing and collection of firewood are the two activities that most effect the dynamics of tree formation distribution in the Bamba site. A study of the patterns of this dynamic in the Bamba observatory has been thoroughly analysed (Dembélé et al., 2006) in relation to the local practices, the village layout, the wells and the Niger River. Two gradients of tree vegetation have been identified: a north-south gradient for tree density and intensity of wood removal and a concentric gradient around wells, with regard to regeneration.

Tree density and wood cutting intensity increase from north to south. The explanation for this gradient is the quantity of groundwater and the human pressure which depend, respectively, on the distance to the Niger River and to the villages.

The gradients around the wells can more easily be related to animal stamping. The two gradients are not linear: a threshold distance of 4 km for the north-south gradient, and 9 km for the radial gradient (Dembélé et al., 2006).

In Niger, the exploitation explained above is of major concern in the Torodi observatory and the phenomenon is heightened by growing population needs. In response to this trend, CILSS has launched a programme to establish a wood-energy collection monitoring network for the subregion.

It is noteworthy that Lavauden (1927) was the first to use the word "desertification". He used it to describe the degradation of *Acacia* trees in Tunisia. Aubréville (1949) has also been credited with coining the word which he conceptualised by speaking about degradation caused by wood removal in tropical Africa.

2.3- Ecological trends as indicators of the impact of droughts and anthropic exploitation of resources

Climate variation and man-induced pressure on resources are two driving forces whose dynamics are complex and often synergetic, leading to more or less significant changes in the structure and functioning of ecosystems. These changes, when irreversible at the ecological scale, are said to be directional in that they cause deep and permanent change to the attributes of the ecosystem. This was the case of land degradation and desertification which, by definition, are attributed to man and/or droughts. But even without interventions by man, changes can be

observed, often as the result of natural climatic fluctuations. These changes are reversible by nature and are linked to the normally very variable functioning of arid ecosystems. One of the basic problems in these environments is making a distinction between these two types of dynamics that correspond to two embedded time scales. This situation also brings up the problem of distinguishing between the effects of climate and manmade overexploitation.

The purpose of monitoring, in this context, is to bring out information that can improve our understanding of the processes of change, to identify the significant ones together with their causes and the degree of their implication and, lastly, to validate indicators that can contribute to a diagnostic of the state and levels of degradation, in order to define standards, within a unified framework, for evaluating processes, be they regressive or progressive.

2.3.1- Soil surface state

Edaphic changes are usually much slower than changes to vegetation, flora and fauna. But they can be relatively fast in arid climates (Albaladejo, 1998, Aidoud et al., 1999). Although they are part of a step by step dynamic (Milton et al., 1994), they are deemed undebated indicators of irreversibility and ultimate significant changes in the desertification processes (Friedel, 1991; Floret et al., 1992; Mainguet, 1994; Milton et al., 1994; Jauffret, 2001).

The soil surface state has been recorded through regularly spaced points (usually 10 cm) along a line staked out by graduated ribbons. The soil surface state is expressed in terms of frequency of sanding, coarse elements, coating, plant litter and plant cover (the last element is dealt with separately, cf. infra). Frequency figures are generally assimilated to cover rates. The simplicity of the method and the data analysis procedures make this a very effective tool for long-term monitoring.

Regular measurements, using permanent mechanisms, sometimes bring out major changes.

In the Haddej-Bou Hedma observatory, plant litter frequency is connected to rainfall variations (annual vegetation dries up). Enclosures tend to develop a sealed crust, probably because of the decrease in stamping.

What seems surprising, on the other hand, is the differences in the amounts of coarse matter and sand observed from one year to the next. These variations help us to understand and illustrate desertification and regeneration phenomena but need to be confirmed through more incisive sampling techniques in order to verify the related mechanisms. This could be done in a short-term study.

Soil monitoring in the main Haddej plant groups indicates that soil fertility is low and the organic matter rate is under 1%. On the other hand, information from monitoring the mineral composition of the soil in relation to the quantitative distribution of vegetation shows that under acacia cover, the humidity and nitrogen rates have gone up, which explains the reason for a rich herbage cover in the protected zone, something that was not borne out in the grazed areas. This was confirmed by the higher density of perennials (14 against 3 indiv/m²). In the grazed area, the perennial plant cover, which is lower under acacia, can be traced to the more intense grazing in shady areas.

For certain variables, e.g. evolution of fertility by measuring C and N, values are so low that they push the machine to the limit of its capacity for precision. Thus, besides having to distinguish between levels of natural fluctuation and directional changes, variations caused by the measuring device and spatial variability also must be factored in.

A grazing pressure gradient mechanism, referring to long-term dynamics (some 20 years) in the Sud-Oranais observatory, showed significant changes in the soil and the soil surface (Slimani, 1998; Aidoud et al., 1999). A series of edaphic characteristics was analysed in the steppe along a transect that indicated three levels of grazing intensity, including that of an exclosed plot. The preceding system was composed of alfa steppe, common to the region 20 years earlier and ecologically homogeneous. The results indicate that measurements of edaphic conditions in the exclosed steppe were much the same as in the earlier system, while in the overgrazed steppe, which is the most representative of the current state of the rangelands of the Sud-Oranais plains, the organic matter rate had dropped a significant 38% and the clay and fine silt, 43%. This decline was attributed to the degradation of edaphic functions provoked by irreversible destruction of perennial vegetation, namely alfa (esparto grass), due to overgrazing.

One corollary to soil degradation is increased sand intrusion on top layers due to the removal of the fine fraction by erosion, on the one hand, and/or sand migrating from neighbouring degraded soils. The two phenomena (deflation and accumulation) can occur in the same place, at different times. In some cases, mobile dunes are translocated as a mass.

In many countries such as Mali, Mauritania and Algeria, dune and sand intrusion are seen as key indicators of desertification and are taken very seriously.

In the Bourem observatory, on the banks of the Niger River, major dune movement to the north of the river was recorded (averagely 0.5 m per month) during the ROSELT/OSS monitoring phase. This movement confirms the threats looming

directly over the irrigated cropping zones along the river and to the river itself. Because of the magnitude of the process, the Malian authorities have launched actions to control sand intrusion (protection of crops, water courses and points, settlement areas, communication paths) and have set up a Niger River basin protection agency (ABFN).

In the Sud-Oranais, sand encroachment has been studied from the angle of the origin of the present-day sands and the history of moving sand. The approach was based on the analysis of granulometric, morphoscopic and colorimetric characteristics of the sands in order to work out an overall pattern of wind-induced sand migration and also probably the origins of sand along the three transects in the sample. Results have shown, *inter alia*, that the effective wind-driven sands are the ones that carry particles of 150 to 300 μm in diameter. Sand migrations follow a W-NW course. This was also observed in the Sud-Algérois steppe by Makhlof (1992) and challenges the hypothesis on sands from the Sahara following a north to south course.

Measurements made in the El Omayed observatory show active sand migration in certain zones. In a study of this process, the size of the sand grains was differentiated showing an increase in the fine sand, as observed by Aidoud *et al.*, (1999) and Huang *et al.*, (2007) in the steppe degraded by overgrazing.

2.3.2- Water resources

Water scarcity makes it essential to monitor water resources in arid environments. In the observatories, water resources monitoring is done through evaluations of the water status and the quantity and quality of water available for agriculture and livestock production. Water monitoring is more or less detailed and in certain cases, brings out trends that seem alarming.

In the Haddej-Bou Hedma observatory, the status of water from rainfall, groundwaters available for irrigation, and soil losses from hydraulic erosion are monitored and compared to the systems in the protected zones, considered as the reference system. Groundwaters are monitored by measuring water salinity in 22 surface wells. The quality of the underground water used for watering garden crops (submersion or droplet irrigation) has not changed much.

Significant trends have been noted in other observatories. In El Omayed, there has been a significant increase in soil sodium, sulphates and chloride. At Menzel Habib, evaluation made during two cropping seasons indicate an increase in conductivity from close to 2 to 10 mS per cm, probably caused by submersion irrigation. A significant increase in electric conductivity at Oued Mird is indicative

of a certain soil salinisation, that could be explained by the concentration caused by sporadic drought, but the observatory team showed that it was connected to water abstractions for irrigation from the groundwater tables.

Overuse of aquifers and degradation of water quality at Oued Mird have been described. The explanation lies in the increased pressure on the phreatic zone which is increasingly solicited to supply water to the growing number of wells. This also seems to explain the drawdown of the phreatic zone even to the point of depletion in certain places, accentuated by the most recent droughts.

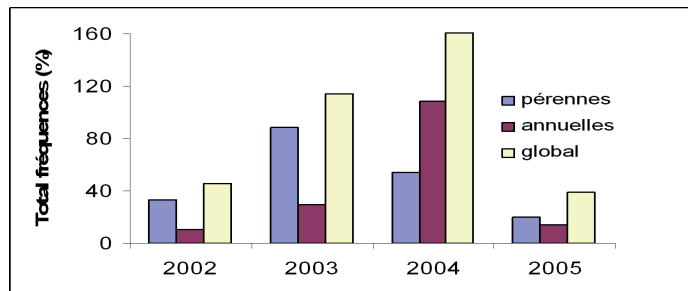
In the Sahel, no trends have been reported except for increased pollution of temporary ponds continuously utilised by animals.

2.3.3- Biodiversity: habitat, vegetation, flora and fauna

Direct observation of the vegetation mainly indicates inter-annual variation due to rainfall variation (pluviometry).

The Haddej-Bou Hedma observatory is a good example. The results (Fig. 4) show the significant link between variation in vegetation frequency and rainfall levels ($p < 0.05$). This link is less clear for the annuals and perennials considered separately. Although the annuals respond strongly to rainfall, they seemed to fall behind the perennials in 2003. The following year, the reverse was witnessed. The annuals seemed more sensitive to the accumulated 3-year rain deficit (1999-2002). The perennials were less sensitive due to their root structure which allows them to reach deeply infiltrated waters at times of the year when the annuals and short-lived perennials cannot.

Figure 4: Inter-annual variation of vegetation in the Haddej-Bou Hedma observatory (frequencies recorded through point quadrats)



The same can be said about the Bourem observatory. The dynamics of herbage in the Haoussa was monitored between 2002 and 2005 (Fig. 5 and 6). The inter-annual difference can be explained by the difference in rainfall. Ecological conditions and anthropic pressure explain the differences between zones NH, CH and SH.

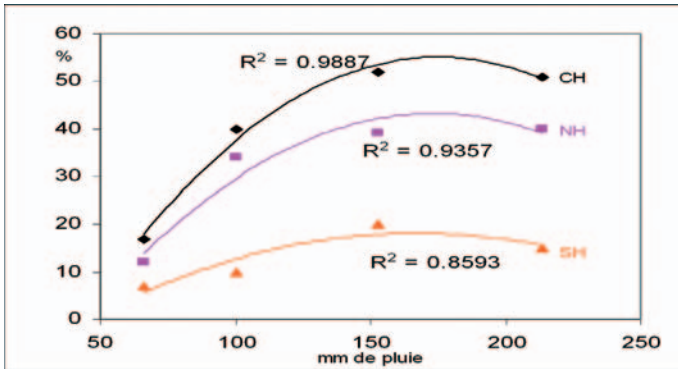
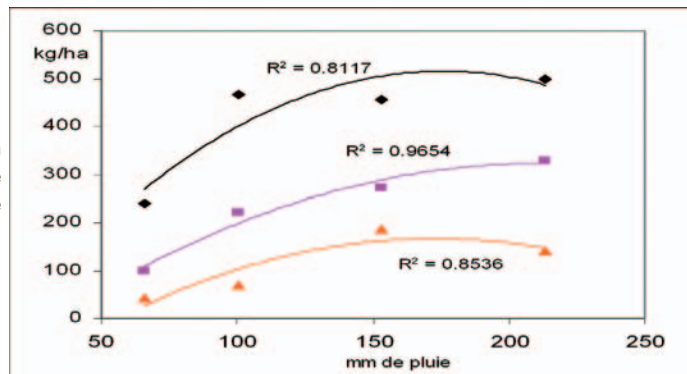


Figure 5: Relation between annual rainfall and herbaceous layer (%) in the Haoussa, the Nord-Haoussa (NH), Centre-Haoussa (CH) and the Sud-Haoussa (SH).

Figure 6: Relation between annual rainfall and herbage production (kg/ha) in the Haoussa (cf Figure 5)



Variations are significant for both cover ($p=0.0371$) and production ($p=0.0049$) of the herbaceous layer. The same correlation is highly significant between annual rainfall and the three parameters being studied.

In Centre-Haoussa, the predominance of perennials (*Panicum turgidum* and *Cyperus jemicus*) in the herbaceous layer is an indication of lower pastoral pressure as well as a higher production capacity when precipitation levels are low.

The regression shows that especially in Nord-Haoussa, rainfall increments are not linear, implying the effectiveness of the rains can reach a threshold after which the other resources no longer suffice to sustain the primary productivity.

Concerning diversity, the same results were obtained using the Shannon index.

The low herbage production in Sud-Haoussa is a result of degradation from overgrazing. This situation characterises the whole territory between Gao and Bamba (250 km) because it is so close to the Niger River, the only permanent

source of water. In order to assess the production potential of Sud-Haoussa, it would be worthwhile to evaluate the lands under enclosures.

Ancient data were the only source for calculating long-term trends for diversity. In the El Omayed observatory, monitoring specific richness not only indicates a close link with rainfall but also 26 species that were threatened with extinction because of human activities thereby reducing plant density. The perennials, half of which are woody species, are the ones at stake. In the observatory, except for the inner plateau, a period of serious decline was followed by a regeneration of floral diversity towards the end of the 1990s. Renewal was also evident in the biological spectrum with the return of woody species (chameophytes and phanerophytes). Diversity indices α and β indicate that the ridges and inner plateaux are the most favourable habitats for floristic diversity and host the most diversified communities and greatest specific plant renewal. In this observatory one of the conclusions on the diversity issue was that the results obtained, in certain cases, raised queries on the effectiveness of enclosing plots to protect the biodiversity.

A list of the species that require special protection because of their status as threatened, vulnerable or rare, have been drawn up based on the inventory of floristic corteges in the Tunisian observatories that may apply to Haddej-Bou Hedma. However, in this and several other observatories, the inventory of the floristic diversity was incomplete due to drought spell that occurred during the observation period.

Establishing trends of wildlife became even more difficult, but previous surveys in the ancient refer to certain species as "extinct" or "disappearing".

In Haddej-Bou Hedma, the fauna inventory indicates that there are about 300 species including about 100 vertebrates, 167 insects and 41 arachnide. Many species no longer exist, e.g. among the big mammals, the Dorcas gazelle (*Gazella dorcas*) and the moufflon (mountain sheep) only exist in the wild in barely few accessible refuges. One of the prime reasons for starting up the parks was to protect the wildlife. Since their creation, no or fewer species have disappeared. Moreover, more species have even been introduced or re-introduced into the parks, e.g. the Addax and Oryx antelopes, the Barbary sheep (*Ammotragus lervia*), and the red necked ostrich (*Struthio camelus*), all of which are adapting well.

The inventory of the wild fauna in the Oued Mird observatory only covered the vertebrates. There is a list of birds in the inventory with 68 species representing 85% of the potential list based on the bibliography. The ethological analysis of the avifauna shows that cropping areas have the largest number of species while the

smallest number is in the reg. One-third of the reptiles found in the Oued Mird valley are considered to be part of the rare and/or threatened species. Some have long been captured, mainly for the traditional pharmacopeae, such as the spiny-tailed lizard (*Uromastix acanthinurus*) and the monitor lizards (*Varanus griseus*). Large mammals like the Barbary sheep (*Ammotragus lervia*), Cuvier's Gazelle (*Gazella cuvieri*), Dorcas gazelle (*Gazella dorcas*) and the striped hyena (*Hyaena hyaena*) were found in the Oued Mird valley until recently. They seem to have survived in the neighbouring mountains and, if reintroduced with time, they may repopulate the area.

In terms of the **vegetation**, regressive dynamic trends were shown based on ancient data. This was the case in the Sud-Oranais steppe mentioned earlier with regard to the soil in permanent station sites, a situation similar to Menzel-Habib in Tunisia.

For close to forty years, a large amount of scientific work has been carried out in the Menzel-Habib observatory and has produced rich and diversified results (Jauffret, 2001, ROSELT/OSS CT 4, 2004).

The badly degraded spontaneous vegetation idominates the steppe but also depends on the nature of the environment by *Stipa tenacissima* (alfa), *Gymnocarpos decander* on skeletal soils (lithosols or regosols), *Artemisia herba-alba* on silty soils and *Rhanterium suaveolens* on sandy sierozems.

Changes in this site have been very profound (Le Floc'h et al. 1995; Jauffret, 2001) benefiting from the run-off waters, nearly all of the steppe has been cleared and given over to cereal cropping on sandy steppe previously reserved for extensive grazing. These changes have made the omnipresent æolian erosion of sandy soils and water erosion of silty soils even worse. Alongside agriculture, the main land uses include grazing on rangelands constantly reduced in size and, ergo, overgrazed, removal of wood as a source of household fuel and fibre for local crafts. Ecological diagnostics in the 1970s have been used to make models (Floret et al., 1978) of possible eco-system dynamics. Simulations were to last 25 years, using 5 land pressure scenarios including: 1 = maintaining the present system, 4 = optimal localisation of crops, and 5 = pastoral management. According to the evaluation made at the end of the 25-year period (Jauffret, 2001), scenario 1 best fits the model although the degradation rates are higher than in the simulation, e.g. the steppe with *Rhanterium suaveolens* "in good condition" hardly exists anymore because of rangeland farming and overgrazing. The widespread extension of certain facies such as *Astragalus armatus* observed at Haddej-Bou Hedma was well identified (Floret et al. 1992), but had never been considered since it represents extreme degradation that

seemed inconceivable. The diachronic analysis (Hanafi and Jauffret, forthcoming), that compares situations over several decades, confirms this change.

Rehabilitation tests in this zone have generated very useful information, e.g. the work by Le Floch'et al. (1995) on two systems in the dynamic sequence with *Rhanterium suaveolens* and *Artemisia herba-alba*. In addition, there has been other protection and improvement work by Jauffret, (2001). The general monitoring approach applied to regressive change (desertification) may be used for changes induced by corrective actions according to the trilogy: restoration, rehabilitation, reallocation (Aronson et al., 1993).

In Sud-Oranais (Algeria), a vegetation map was made between 2000 and 2004. The distribution of physiognomic units was compared to the one made in 1977 and 1978 (CRBT, 1978). The evaluation of the lands occupied by the physiognomic units essentially indicates the regression of alfa steppe from 520,000 ha in 1978 to 140,000 ha in 2004, sagebush from 130,000 in 1978 to 13,000 in 2004, and esparto grass from 570,000 ha in 1978 to 58,000 in 2004. This areal evaluation hides another regression, the regression of the density of dominant species. Records show an undeniable extension of halophile formations and a certain stability in the matorral and psammophile formations. Compared to 1978, the vegetation landscape was (54%) composed of ecologically less demanding and/or less palatable species (so called "degraded steppe") that supplanted the earlier dominant species. As concerns the plant cover, in 2004 the overall plant cover was 10% lower on 85% of the observatory lands, and the land is mainly used for grazing. Overgrazing is the cause of nearly all recorded degradation.

Not everyone agrees that overgrazing is one of the causes of desertification. This notion often stimulates fierce debate (e.g. Davis, 2005). Without going into details, in order to understand various shades of meaning, we need to remember that from an ecological vantage point, the main impact of livestock production is the removal of plant material by domestic animals; and that the impact is not always negative (McNaughton, 1983). When grazing and primary productivity are at equilibrium, they can be seen as a normal process in the overall functioning of ecosystems with a long pastoral history (Drent and Prins, 1987; Fresco et al., 1987; Van Andel et al., 1991; Noy-Meir, 1998). The state known as alternative stable states (Westoby et al., 1989; Aronson et al., 1993) in the arid steppic rangelands have been maintained thanks to thousands of years of pastoral production, which has even become necessary for these lands. In certain cases, lack of grazing is a cause of disturbance (Laycock, 1991; Amiaud et al., 1996).

2.4- Socio-economic impacts

2.4.1- Migration

Migration is a phenomenon primarily induced by population growth and/or impoverishment. It is also seen as a way to avoid activities considered "degrading", to improve income levels and thus the quality of life, and to help part of the family that remains at home. In the Ferlo, most migrants are between the age of 15 and 35 years . The migration rate is soaring with the 1990s rates doubling that of the 1970s-80s; and seven times higher in the 2000.

In the Ribeira Seca observatory (Cape Verde), emigration affects 24% of the households (average of 6 persons, of which 3 are of the working age). For the last ten years, agriculture has been somewhat forsaken in the Godim area.

In southwest Niger, where the Niger observatories are located, better climatic conditions attract people from the more arid north. This seems to explain the uneven population distribution between regions, which is becoming worse despite the authorities' efforts to maintain the people in their area of origin by supporting various agricultural activities.

Migration is also common in the northern part of the Sahara. In many families certain members are obliged to work outside their tribe as workers, traders, etc. (e.g. 41% at Issougui) or even emigrate abroad (12% of the Aït Zekri d'Issougui families).

2.4.2- Sedentarisation

In the arid rangelands around the Sahara, where rainfed agriculture is too uncertain, rearing domestic animals is one way to make good use of ill-watered lands. Converting plants into meat is the most profitable way to use these resources if well-adapted animals and adequate rangelands are available.

To develop trade and to benefit from widely dispersed resources, nomadism used to be the most common lifestyle throughout these rangelands. As long as the population density remained low, pastoralism combined with nomadism allowed for balanced resource management (Ibrahima, 2004). This lifestyle was seriously challenged with the advent of technologies that allowed for greater efficiency and well-being (transport, schooling, healthcare, communications, the media, etc.). The nomad population is becoming much smaller and is being relegated to the Saharan and pre-Saharan zones.

Herds are still driven on rangelands earmarked for nomadism or transhumance, two concepts that are generally confusing, although the former is a lifestyle while the latter is more of a production system (Vignet-Zunz J., 1979). In this report, the focus is more on transhumance as a production system that can, nonetheless, be seen as a component or a vestige of nomadism. Sedentarisation seems to be a general trend throughout the circum-Saharan zone with variations related to extent and underlying reasons. What do the evaluations made in the ROSELT/OSS observatories tell us about sedentarisation nowadays?

The northwestern coastal zone of Egypt used to be inhabited by Bedouins who generally lived a nomadic life (van de Ven, 1987), under the poverty threshold. To encourage nomads to settle down in 1964, the government promulgated a law granting them access to land ownership, with the provision that perennial plant species be grown. This measure stimulated sedentarisation and the cultivation of fruit trees.

Thirty years later, (El-Knowy, 1993) excluding sedentary herders who live in groups, there are two social categories that stand out among livestock producers: the semi-nomads who live in scattered habitats installed near their lands, and Bedouin nomads who live in tents in the heart of the desert and grow cereal crops in rainy years on land that belong to their tribes or on communal lands.

In arid Tunisia (**Haddej-Bou Hedma and Menzel Habib**) sedentarisation seems quite advanced since close to 80% of the lands have been privatised (e.g. Menzel Habib observatory). Sedentarisation, as an example in El Omayed was favoured by Tunisian government some fifty years ago when the state started encouraging tree crops. This brought about serious change in land uses. Sheep and goat rearing used to be nomadic but now is practiced under semi-sedentary systems with transhumance only drawing on nomadism to borrow some of its practices and farmers moving their animals over much smaller areas.

In the **Sud-Oranais steppe rangelands**, livestock production is still the dominant economic activity which explains why overgrazing is considered to be the main problem in this observatory. According to surveys, about 40% of the herders move their animals over long distances, (achaba or azzaba type system) but with only 14% of the households living in tents. Traditionally transhumance was a winter movement (azzaba) to the southward Saharan rangelands followed by a northward movement to the cereal growing zones after the summer monsoon (achaba). The Azzaba protected the cattle against the cold winter temperatures that characterise the steppe and the Sahara Atlas. In the traditional achaba, herders of one tribe went to arch lands, passing through transhumance corridors,

after transiting through holding zones before reaching the cereal growing zone (point of arrival generally located at the southern piedmont of the Tellian Atlas).

Crop farming is becoming more popular in this area but has not reached similar levels as in Tunisia and Egypt because the climate is less favourable (harsher in the winter). The decline in nomadism also seems to be influenced by change in practices, as can be seen from the following indicators: most herds are being moved over shorter distances (less than 40 km), increased transport of transhumant animals by lorry, generalisation of feed supplements which contributes to the dominance of the Baida sheep (because of its white colour) over the Hamra breed that is hardier and was formerly the most dominant breed in the nomadic herds (Aidoud & Nedjraoui, 1992).

In the **pre-Saharan piedmonts of the Moroccan Atlas** (Oued Mird, Issougui), the nomadic system held out longer than in other North African areas but has recently taken a serious downturn. The pace of sedentarisation in the Oued Mird Valley and in the neighbouring region has been irregular during the last 30-40 years, with an average settlement rate of about 5 households/year. The 2004 Oued Mird observatory report shows that the number has increased to 15 Aït Isfoul nomad families staying in the region and use the same rangelands.

The relatively recent tendency towards sedentarisation probably explains the lighter pressure on the pastoral resources which actually characterises the region (Davis, 2005), making due allowances for the eco-climatic potentials. Davis seems to take this region as an example of a preserved ecological situation, thus challenging alarmist writings (e.g. ORMVAO, 1993; Thiault, 1994; PROLUDRA, 1997 in Davis, 2005) that incriminate herders for overgrazing, which is often considered to be the primary cause of desertification (cf. debate on the concept of desertification).

In **West Africa**, pastoralism is an ancient specialisation of certain ethnic groups such as the Peulhs (Fulani) and space is governed by traditional management rules (Thébaud, 2001). These rules are also applied among the Haoussa in Niger, the Touregs and Tamachek in the north of the Sahel and the south of the Sahara (Ibrahima, 2004). The grazing areas and the water points are generally intended for collective use despite the existence of a significant informal market in certain places (Mathieu, 2001).

Studies in the ROSELT/OSS observatories in West Africa indicate that sedentarisation is not a major trend as compared to the observatories in the north of the Sahara. Although certain authors and indicators confirm the existence of sedentarisation in certain pastoral areas, e.g. on the rangelands near the River Niger in Mali, and in Ferlo region of Senegal.

When Mali became independent, in an effort to ensure better control of the population and livestock production, the government encouraged the nomads to settle down. State-operated stores were created to facilitate the agricultural supplies (Baudoux et al., 2005). A relative specialisation of land use along ethnic lines in the Bamba commune has been described: most farmlands belong to the "Armas", and the rangelands are for collective use but are governed by rules dictated by customary law. The use of wells, however, are the priority right of the tribe that contributed to digging them. Management of the grazing areas in the bourgoutières (wetlands) was also dictated by rules that were different from the ones set out in the general regulations in force. Sedentarisation and population growth have led to increased interest in farming, which is also encouraged by foreign aid (Mathieu, 2001). Alongside increased pressure on arable lands, the stocking rate near the river is rising as the majority of the population from northern Mali settle there to water their animals during the dry season. Hence, conflicts are therefore inevitable between local and state authorities. Most conflicts concern the use of the arable lands along the river or in the river beds after the water receding, the boundaries of farmlands, the sharing of inherited lands, the use of fallow land, and water access. Advisory councils, imams and other local authorities usually mediate and solve these conflicts at the local level.

In the Niger observatories, agriculture has taken over relatively more land due to higher rainfall levels. Agricultural intensification means less down time for fallowing but sedentarisation as such, according to recent studies, is not a significant phenomenon. In general, there is a more pronounced tendency towards sedentarisation in the northern part of the Sahara. Initially, with State encouragement, sedentarisation allowed the local populations to develop alternative activities and to diversify their sources of income although livestock production still forms the main backbone, and practised under extensive mode but with less distant movement than during the period dominated by nomadism. Sedentarisation may seem like a corollary to crop farming, since the adjunct is less grazing land and hence less grazing land degradation by overstocking. But the shortage of forage (e.g. Sud-Oranais) and/or water points (e.g. Bamba commune), either due to declining resources (degradation of plant canopy and water quality) or the increased numbers of animals can lead to a similar process, with less animal movement. Thus despite the difference in sedentarisation levels between the north and the south of the Sahara, there seems to be some convergence in practices connected to or favoured by sedentarisation.

2.5- Significance of trends

A number of significant biophysical changes have been demonstrated in the ROSELT/OSS observatories, changes that have been monitored for at least ten

year. Are they significant in the long run? How can these changes, which have been observed in specific situations be included in a larger framework, at the subregional or regional level? What should be the position of these changes in the theoretical dynamic model of the arid ecosystems? The current debate on these questions is so contentious that at this stage, only partial answers can be given.

2.5.1- Significance of climatic trends

For all the sites and observatories, the changes, especially in precipitation, can lead to statistically significant trends for the future, however lengthy. At El Omayed, for instance, monitoring records show that during a 25-year observation period, there has been a steady rise in air temperature (2 to 3°C), relative humidity (10-15%), and rainfall (20-30 mm/yr). For the Oued Mird observatory, there has been a steady drop in rainfall ($p < 0.05$) between 1988 and 2003. This evolution also applies to the Ribeira Seca observatory, but needs to be incorporated in a longer time series. In the Hautes Plaines du Sud-Oranais observatory (El Bayadh station), data from a 20-year period (1971-1989) also shows a significant drop in rainfall ($p < 0.05$). When incorporated in data for a longer period of time (121 years), however, this relatively dry period indeed appears as the longest at the scale of one century, but does not reflect a significant trend for the series as a whole.

On the one hand, it is difficult to assert the existence of a long-term trend, especially an "aridification" trend, but, on the other hand, it is highly probable that the extended drought spells have an impact on the desertification processes. The cause and effect link, however, is indirect and should be seen via overexploitation of natural resources, especially through overgrazing (Le Houérou, 1969; Aidoud and Touffet, 1996) or via the expansion of shifting agriculture (Floret et al. 1978; Le Floc'h et al, 1995, Jauffret, 2001). Moreover, Le Houérou pointed out in 1969 that "the desert is created by man; climate is nothing more than a favourable circumstance".

2.5.2- Place of desertification in theoretical dynamic models

A coherent theoretical framework is needed to interpret the results of the data analyses and to prepare decision-support products.

Paradigms play a critical role in nature-related sciences through the models that are created to identify problems and interpret results and thus have a strong effect on legitimising hypotheses and the solutions proposed (Briske et al., 2003). The failure of management models for grazed arid ecosystems based on the classical successions theory (called the Clements theory) could be explained by the inapplicability of this theory to the functioning and dynamics of arid systems. The

alfa steppe, that until recently formed dense, homogeneous clusters in the Sud-Oranais observatory, is a good example. These formations of ancient glacia seem to have been maintained in a state of metastable equilibrium that some call a "fossile" state with a high level of vulnerability. A brutal, profound change in herding practices and higher grazing pressure caused irreversible destruction in just a few years (Aidoud et al., 2006). These were singular steppe areas that did not follow the classical successions pattern found in the "Aleppo pine series", as was the case until recently.

The current debate on models of arid ecosystem dynamics indicates that the international scientific community apparently has not yet fully developed **scientific theories** on the dynamics of these ecosystems (Briske et al., 2003; Richardson et al., 2005; Hein, 2006; Retzer 2006). To formulate the theoretical bases and the dynamic models that can explain the current processes and support the choice of reference systems for restoration and rehabilitation actions for degraded lands will require more profound analyses. This will require considerable effort.

3- Data management and Decision-Support Products (DSP) —

3.1- Local Environment Information Systems (LEIS)

The LEIS was produced as part of ROSELT/OSS work on biophysical and socio-economic data processing and management. LEIS is composed of four subsystems: database management, geographic information systems (GIS), graphics, and modelling. The LEIS principle provides for the modelling of:

- the structure of a territory (e.g. observatory) subdivided into landscape units (LU), demarcated according to their biophysical characteristics, and into combined practices units (CPU) defined on the basis of natural resources exploitation practices. The intersection of these two spatial structures determines the spatial reference units (SRU);
- the functioning and evolution of the system at a given time scale, thus expressing the real dynamics (as recorded) or the dynamics simulated according to predefined scenarios.

The application of LEIS in the Menzel Habib observatory (Tunisia) is given as an example, with a brief description of the general principles of the LEIS system. For more information and detail, see Loireau (1998), ROSELT/OSS DS3 (2004), Loireau et al. (2005) and, more specifically for the Menzel Habib observatory, see Sghaier et al. (2005). The modelling period in this observatory ran from

2001 to 2004. Surveys and investigations were made between 2003 and 2005. There were 22 "centres of activity" (CA), in other words urban centres that were considered to impact the natural resources exploitation practices. But despite their importance as a place for watering the animals, the water points, for instance, were not considered to have any structuring effect. The CAs were demarcated according to elementary territorial units (the imada) showing the number of households, inhabitants, and livestock.

Soil use

Analyses based on satellite images and ground truth have been used to identify 13 soil use units (Table 2)

Soil use unit	ha
<i>Stipa tenacissima</i> and <i>Artemisia herba-alba</i>	11,150
<i>Rhanterium suaveolens</i> and <i>Astragalus armatus</i>	22,796
<i>Arthrophytum schmittianum</i> and <i>Salsola vermiculata</i>	698
<i>Arthrophytum scoparium</i> and <i>Helianthemum kahiricum</i>	1,601
<i>Atractylis serratuloides</i> , <i>Astragalus armatus</i> and <i>Salsola vermiculata</i>	15,703
<i>Atractylis serratuloides</i> and <i>Pituranthos tortuosus</i>	23
<i>Lygeum spartum</i> , <i>Atractylis serratuloides</i> and <i>Gymnocarpus decander</i>	1,198
Halomorphic rangelands	183
Exclosed land and forest plantation	1,087
Crops (cereal and/or tree)	20,938
Mixed unit: rangeland 30%, crops 70%	2,431
Mixed unit: rangeland 50%, crops 50%	2,673
Mixed unit: rangeland 70%, crops 30%	1,540
Agriculture after jessours	7,108
Garaa	1,170

Table 2. Soil use units in Menzel Habib observatory

Landscape units (LU)

Landscape units were elaborated on the basis of a morphopedological typology that combined geomorphologic and edaphic data derived from cartographic documents:

- topographic maps: two at a scale of 1:100,000;
- soil maps;
- geomorphologic maps.

After processing (digitalisation, geo-referencing) and crossing the data was grouped into a (17 soil classes and 8 morphologic classes) a series of 1,288 elementary units, drawn up according to 52 morphopedologic classes, were summarised and represented in 351 units that referred to a final panel of 13 "soil aptitude" classes.

- silty-sandy soils in the depressions;
- sandy-silty soils in the depressions;
- garaats soils (depression);
- glacis soils with crust;
- raw mineral soils in the glacis;
- alluvial soils in the plains;
- piedmont soils;
- silty-sandy soils in the plains;
- sandy-silty soils in the plains;
- sebkha soils (saline depression);
- soils of a drainage basin;
- exclosed soils (mise en défens);
- red soils.

Creation of potential territories of exploitation (PTE)

A PTE is a CA connected to a structuring activity, (e.g. starting to farm a land) weighted according to a variable (e.g. population, in this case). In the model that was used (see Thiessen in Loireau et al. 2005), for each point in space, a criterion is calculated that combines weight "w", and the distance "d" to the CA using the equation $\sqrt{w/d}$. The space is then subdivided into 22 PTEs, using this criterion, connected to the 22 CAs.

Combined practices units (CPUs)

The CPUs are divided into the six types described in Table 3.

Each CPU is characterised by a dominant, but never single, use at the selected landscape scale. The aim is to recognise the dynamics of these practices and their impact on the natural resources.

CPU	Cer.	Mar.	Oli.	Snu	Par.	Fri	Total	Characteristics
CP1	5 (20)	0	20	20	40	15	100	Last "Jessour" oil crop (water retention structure): upstream part, sharp slope, drainage basin
CP 2	10 (35)	0	45	10	10	25	100	"Open field" oil crop on plain and low-lying land without water infrastructure
CP 3	20 (45)	0	10	15	10	45	100	Rainfed cereal crop
CP 4	10 (40)	0	40	10	10	30	100	Cereal crop and oil crop with "tabia"
CP 5	15 (30)	30	10	15	0	30	100	Irrigated crop (small area, market gardens) + rainfed cereal crop (45 or 15/30) + tree crop
CP 6	5 (15)	0	5	25	55	10	100	Pastoral rangeland with steppe, cereal crop + oil crop

Table 3. Combined practices units in Menzel Habib observatory

Figures for each CPU give proportions (in %) of land area per soil use practice or type:

Cer. = cereal cropping; Mar = market garden; Oli.: oil crop; Par = steppic pastoral rangelands; Fri = cleared land; Snu = bare land.

Figures between parentheses for cereal crops indicate land area given to this practice in rainy years.

In average or dry years the rest of the land is left to rest (called "fallowing" in other observatories).

The agricultural yields (kg/ha) have been evaluated for each landscape unit through surveys and bibliographic data using combined practices (CP) types and soil aptitudes.

Five strategic human groups based on land use have been identified: no activity, large livestock and tree producers, oil crop and livestock producers, medium farmers, irrigators. For the animals, three strategic groups have been defined on the basis of pastoral activities (non-transhumant, locally transhumant and transhumant outside CA).

Annual agricultural needs are calculated in kg per strategic group in order to evaluate and size the lands to be exploited. The needs are evaluated using variables called "global constants" linked to the consumption of the agricultural production **cc** for timber **ct** and the forage **cf** evaluated at 0.23 kgDM/day/head, the commercialisation **co**, the seed **se**, and the sown land surface **ss**.

The variable **ct** has been evaluated at 0.07 kgDM/day/pers. and **cf** at 0.23 kgDM/day/head.

The variables **cc**, **se** and **co**, factoring in home consumption, seed storage rates and proportions sold, were calculated using the following data:

- cereal crop production **pc** and sown surface **sc** per household and cereal crop yield **rc**.

- olive tree production **po** and number of trees **no** per household, and olive tree yields **ro**.

For a strategic group of persons nh , the needs, bh are:

- $bh = (cc + se \times ss + co).nh$

Each pixel (resolution 300 m) has been informed by:

- the 'own effort' **ep** (effort propre) that is evaluated for each class of combined practices, based on investments (mechanisation, development, inputs, subsidies, labour and equipment). Examples: class PC6 (pastoral rangelands) and PC5 (market gardens) have **ep** of 0.56 and 1.00 respectively;
- effort **E**, calculated according to practice type, as a function of ep , the distance to the CA, penalisation for distance and distance threshold beyond which the probability for agricultural production to occur is low;
- agricultural production **Pr** combining cereal crops and olive trees;
- the "maximum interest" defined as the relation to this pixel of production **Pr** to effort **E**;

This information has made it possible to delineate the effective exploitation zones (CPU envelopes) that can meet the needs. If the needs are not satisfied, the zone is considered to have a "deficit".

The CPUs are obtained by combining the CPU envelopes and the combined practices (CPs) of maximum interest.

Using available data and offtake of agriculture, forage and wood resources, the observatory made assessments and corresponding maps that show the spatial distribution of the impacts of various usages. The maps show that 'high' often coincides with highest availability. A negative assessment shows a risk of degradation in the Menzel Habib observatory that is expressed in relation to the surface, is 28% for agricultural activity, 30% for pastoral activity, and 24% for wood offtake. These preliminary estimates are not very precise; more precise results will be obtained from surveys at the plot level.

Application of the LEIS system is more or less advanced in the other observatories:

- The LEIS tool was first used in the Dantiandou observatory (Loireau, 1998; ROSELT/OSS DS3, 2004; Loireau et al., 2005; Loireau, forthcoming).
- At El Omayed (Egypt), the LEIS tool was used to show the breakdown of the main data required for digitalised modelling at 1/25,000: the topography, soils (according to the map drawn up by FAO). Processing by remote sensing

was done on a Landsat TM scene in 1984, on which vegetation units were geomorphologically demarcated. The available and compiled field data were adjusted to the standardised working scale. A model was made using the LEIS procedure, as described in the methodology guide.

- In the Ferlo observatory (Senegal), 71,000 ha of agro-pastoral land have been modelled using LEIS in the Ouarkhokh commune. This was an exercise carried out between 2000 to 2005 to make a LEIS prototype, including observatory characterisation and data collection (existing and field data for the model were collected); after which, the whole modelling procedure was implemented.
- At the Issougui observatory (Morocco), after careful thought, the southern part of the observatory (Saghro) was selected for modelling because of the area's social dynamics, accessibility and data availability.
- Hautes Plaines Steppiques (Sud-Oranais): the biophysical part of the information system is being constructed. Some socio-economic data still need to be collected and put into the system and the current working scale is 1/200,000.
- In the Ribeira Seca observatory, the survey needed for the LEIS prototype was made in 2005.
- The report on the Oued Mird observatory (Morocco) indicates that implementation tests have been carried out and that the geo-referenced data had to be reconstructed.
- For the Bourem observatory (Mali) and the Haddej-Bou Hedma observatory (Tunisia), there are no special indications in the reports that were analysed.

3.2- Metadata bases (ROSELT/OSS Mdweb)

This tool is designed to define, describe and locate available data and information relating to the observatories. In the Mdweb framework, the metadata are focused on a series of descriptive such as summaries, keywords, date, language, geographic scope and references, sources of data, etc.

This tool has been implemented in the El Omayed, Ferlo and Menzel Habib observatories.

3.3- Decision-support products (DSP)

Decision-support products (DSP) can be defined in various ways, according to Matthies et al. (2007), i.e. as interactive, flexible, adaptable, computerised systems to assist in identifying and solving complex, unstructured management

problems and thus contribute to making wiser decisions. The environmental DSPs are frequently composed of several models, databases, evaluation and diagnostic tools. They include a graphic user interface that is often made using spatial functions for data management with data from the geographic information systems (GIS). The DSPs use data and models, and offer an easy, user-friendly interface for the decision-makers that includes tool-specific levels of specialisation and user capacity. Furthermore, the DSP is often constructed using an interactive process and offers assistance and support for decision-making phases.

The decision support products are an expression of the transfer activities of scientific research institutions. They can be very useful tools in planning and managing ecosystems. The DSP can contribute to effective exchanges of information between experts and a whole range of stakeholders (decision-makers, operators, managers, etc.). But the effects of DSPs are often considered limited to certain ecosystems (Goosen et al., 2007) i.e. the arid environments.

The reliability, effectiveness and precision of DSPs depends entirely on the level of knowledge of the environmental state (environment and resources) and the dynamics of the ecological, agrarian and socio-economic systems. Todd (1999) felt that a complete detailed system had to be developed in order to evaluate the adequacy of the environmental information available to construct a DSP to meeting the needs of the managers and to establish procedures for systematically updating the information on these systems. This idea was based on the fact that the quality of management decisions predicates on the quality of the information used to make it.

Besides data availability, one of the challenges that contribute to failure or irrelevance of the DSP was that very often, the DSPs are imposed or managed by the technological tools more than by the demands of the users for whom these tools were created (Goosen et al., 2007).

The form of the DSP will depend on data availability and quality. For the ROSELT/OSS observatories, the products selected for this report are described as spatialised information supports (maps) and LEIS (local environmental information systems) that allow for data capitalisation and data incorporation in procedures for evaluating and representing resources.

Observatory	LCM/SM	Pedology/morphology	Infrastruct./uses	State of biodiversity
El Omayed	LCM Comparison 1988-1997 (in SPOI) sat operational base for monitoring. LCM: 2000-2001 (landbat Tiv) Diachronic analysis	Photo-interpretation (19-54, 62,70): field study detail at 1/25000. 2005: definition of soil classes	Inventory + localisation of water points 2004. Utilization map, completed, arvision., agric. lands, walls. Since 1999 pilot zones to update GIS: plant cover, list of species with cost. Abundance	List of threatened species
Menzel Habib	SUM: 13 units of SU, 1/100000 - Diachronic analysis	16 pedo units 1/100000 (2005); map 8 morpho units; 13 morpho-pedo units.	Map of WSC structures. Inventory + localisation of water points. Irrigation aptitude map (provisional outline): cross of morphopedologic map x water mineral quality map. #36000 ha irrigable (10^4 soil)	List of threatened species
H. - Bou Hedma	LCM 2000: 16 covered units: Im. Sat. + doc + ground check. LCM 2004: monitoring land cover by multi-thematic cross-checking.	2004: 33 profiles (6 soil classes) + outline of pedologic map. Outline of morphological map through topogr. slope - landscape contouration (landbat Tiv 2003) + field check. Morpho-pedo crossing (on GIS).	Map of WSC structures and sand intrusion control measures.	List of threatened species
Oued Mird	11 vegetation units since 2000, demarcated 2004 ASTER image + field validation LCM 2001: revision 19 units: 14 units land cover at 1/200 000	Outline pedol. map. pedol. profiles types (1999-2004). Outline geomorphol. map. Morpho-pedol. Outline underway.	Inventory + localisation of water points	List of flora and fauna. Indication of threatened species
Steppes Hautes Plaines	LCM 2004 (physiognomy, vegetation): changes compared to 1978 (LCM (physiogn units. 1st sp dom.)		Inventory + localisation of water points	Floristic list + taxonomy (families of species) + lat. spectrum + phylogeographic spectrum
Fello	LCM (in Lincat ETM 2002): Ground check (technical form recorded). 5 physiognomic units depending on strat. Vertical	Morphopedol. map (2003-2004): 1/50000: 7 units + agric. aptitude map of lands cropping requirements + climate + pedol. map.; 6 aptitude classes.	Inventory + localisation of water points	
Ribeira Seca	4 main land cover units: crops (dominant: maize / groundnut), fallow, natural vegetation.	Soil vulnerability to erosion	Indicators of severity of erosion: forms of erosion, quantity of matter displaced related to eroded surface and type of land uses. 21,000 t ha ⁻¹ y ⁻¹ of land displaced.	List of species (flora and fauna)
Torodi-Tarikandil-Dandankou	LCM: 8/9 units, depending on observatory		Water resources map / socio-community infrastructure map	Floristic inventory
Boursen	Landscape unit map. Vegetation 1/200000; 10 units.	Morphologic zoning of sand accumulation to monitor dune movement + particle flows (5 units)	Inventory + localisation of water points	Floristic inventory 52 taxa (42 herbaceous + 10 woody)

LCM: land cover; LCM: land cover map; SU: soil use; SUM: soil use map.

Table 4: Main decision-support products elaborated in the ROSET/OSS observatories

3.4- Indicators of change and trends

According to Turnhout et al. (2007), the first person to use the concept of ecological indicators was Kolkwitz & Marsson (1902). Much later, Ellenberg (1974) developed the notion of indicative value, quantified by the species vs. environment index. Specific indicative values (Ellenberg et al., 1992) are broadly used in characterising the environment with plant communities as bio-indicators.

For desertification, according to Grainger et al. (2000), the first list of indicators was proposed by Berry & Ford (1977) and Reining (1978). Others were proposed at a later date by Mabutt (1986) that included biophysical and socio-economic indicators. In 1999 the CCD's Committee for Science and Technology (CCD-CST) proposed a list of indicators for governments to use in preparing their national reports.

This concept was further refined by Veron et al., (2006) and by Jauffret (2001) from the perspective of environmental monitoring and desertification evaluation (cf. ROSELT/OSS, DS4, 2004).

The environmental indicator concept involves relative values and several embedded levels, which makes it complex and potentially confusing (Turnhout et al., 2007). In this concept, a criterion such as diversity that can be evaluated through an ecological indicator is, in itself, an indicator of ecological quality.

The development of desertification indicators depends largely on the available scientific knowledge on a system's components and their interactions. Scientists are often involved in formulating indicators, which is not an easy task. To start with, is a simplification that expresses an important part of a complex whole that is far from well controlled. An indicator is an image of a system built of elements that seem the most relevant considering the level of knowledge and the level of calibration of the indicator. This entails a certain responsibility, which in turn explains the debate on the choice of indicators and the reticence to adopt the concept.

The effectiveness of an indicator is assessed in terms of its capacity to accurately replace the information that it is supposed to be representing. Since a substitute cannot be a perfect replicate, multi-indicator systems are often used to reduce the risks of error and approximation. A desertification indicator is composed of many quality criteria (Soyza et al., 1998) but are summarised by two criterial: reliability and simplicity.

Desertification is a domain in which knowledge of reference conditions, i.e. structural and functional norms of a situation that has existed or the potential of an

ecosystem are vital. But a desertification indicator is only valid if it can be used to measure change in relation to a reference. This shows the importance of historical ecology or long-term monitoring, the only tools for recalling or recording reference situations.

One desertification indicator that is often used (e.g. Guevara et al., 1996; Prince et al., 1998; Diouf and Lambin, 2001 in RETZER 2006; Hein, 2006) is the decline in rain use efficiency, RUE (Le Houérou, 1984) that implies the relation between productivity and quantity of rain. This indicator is based on the principle that productivity is a key function of an ecosystem and that the RUE provides information on water use efficiency as the leading factor in production, whose quantity is determined by the state of the soil and the vegetation cover. The RUE has often been used as an indicator of change, especially desertification and in most cases, it can replace certain parameters that require cumbersome physiological measuring.

But the use of the RUE index is only valid if precise information is available on the reference system (Le Houérou, 1984; Retzer, 2006). For instance, the RUE may rise in desertified systems because of increased CO₂ in the atmosphere (Veron et al., 2006). It can also go up due to succession stages where one type of vegetation replaces another, e.g. woody plants replacing grasses (Huenneke et al., 2002). The installation of an æolian veil during alfa degradation (Hautes plaines observatory) encouraged the development of ephemeral vegetation with production rates above those of the pure pre-existing steppe.

This brings out the need to use several indicators (multi-indicator system) so that the shortcomings and weaknesses of one indicator can be compensated by the others. Together with RUE, for instance, vegetation type and soil surface characteristics can clarify the reference conditions. This is the next step for the ROSELT/OSS team as from February 2007 as was discussed in the meeting on choosing indicators for evaluation in all the observatories.

4- Scientific achievements

4.1- Optimisation of early work

The Menzel Habib ecological systems have often been studied as part of national and international research projects on desertification (UNESCO, CAMELEO, etc.). Many mechanisms have been introduced to combat desertification. All the previous work made it possible, as of the end of the 1950s, to define a typology of the biogeography and the ecology of these systems (Le Houérou, 1959; 1969) and to evaluate the state of the resources through observations and measurements

expressed on detailed maps of the vegetation covers, rangeland production and soils,(e.g. Floret et al. several references).

During the last forty years, considerable research and study projects (Projects SEMDENE, 1975-1979; REMDENE, 1979-1983) have been devoted to evaluating the state of the environment in the El Omayed observatory (FAO, 1970; Shaltout, 1983; Ayyad & El kady, 1982; Abdel-Razik et al., 1984, 1988, 1991; El Keblalawey, 1994). The socio-economic aspect has been analysed in the writings of Van de Ven (1987), Van Duivenbooden (1987), Abdel-Razik et al. (1984), El-Knawy (1993), Heneidy & El Darier (1995).

The same is true for the Sud-Oranais, Ferlo and Banizoumbou observatories where several teams have analysed the biophysical, social and economic conditions at different periods of time.

Data from early works include biophysics and socio-economics namely; the results of surveys, measurements and inventories stemming from different methods and approaches. It is essential to harmonise data so as to anchor them in a dynamic line of logic or to manage them and use them more expediently. The biophysical inventories, for instance, often include taxonomic and edaphic data that were used to calculate distribution patterns for communities and their inhabitants, or to record monitoring data over a give time period in permanent sites and stations, or to draw up land use and plant cover maps. These data come from different sources and cannot be stored 'as they are' in a database. They first have to be standardised, which is often a cumbersome and time consuming (Piessens & Hermy, 2006). An example is the case for lists of species; their taxonomic references need to be standardised because of changes in nomenclature.

Reports on the El Omayed, Menzel Habib and Hautes Plaines du Sud-Oranais observatories stress the importance of capitalising on this information. In the Hautes Plaines du Sud-Oranais, the description of the ecological trends has drawn heavily on existing data through a diachronic comparison of earlier steppe (Land cover maps of thirty years ago and the present). The analysis of these maps, although difficult to interpret, shows the evolution of the resources and the alarming current situation. This provides a basis for discussions with the managers and the decision-makers on future management and developments.

4.2- Quality of data and scientific results

4.2.1- Strong points

The results briefly described above reflect strong points in the network, as evidenced by the observations and measurements made, the mass of data

collected, the finalisation and integration of ancient data, and the effort to analyse and interpret data in an interdisciplinary framework. What has already been accomplished through the network is a tremendous feat considering:

- the hitherto high dispersal of work and the isolation of the teams involved in the study of the arid ecosystems and desertification along the border areas of the Sahara;
- the difficulty in harmonising approaches when the situations, experiences and problems related to current research projects are very different and diverse;
- the insufficient level of knowledge on the arid ecosystems in general, and on their dynamics in particular because investigations have shown of the complexity of interactions between biophysical and socio-economic factors and differences in scales and levels of action and retroaction between these factors;
- the academic nature of the teams, which are accustomed to being asked for a certain scientific originality that is not compatible with the routine nature of long-term monitoring.

The ROSELT/OSS network has managed to create a sense of cooperation among teams composed of people who, in many cases were total strangers to each other. Now there is a genuine "network life". Some national institutions, to which the observatories are accountable, have taken over long-term monitoring and are applying it in territories and stations outside the observatory zones.

4.2.2- Difficulties and shortcomings

Difficulties linked to long-term monitoring

Long-term monitoring in general, and more specifically via ROSELT, uses approaches that are not common in research activities since they involve continuous monitoring with techniques and mechanisms that require a routine type of work that is not customary in the classical university and academic approaches. This explains a certain number of past and foreseeable difficulties:

- The organisation of networked environmental monitoring requires a certain degree of coordination and permanency at the observatory level in order to maintain the "long-term" aspect. For projects to be renewable is not enough but rather the observatories have to become part of national mechanisms by accepting institutional approaches that are the only guarantee of continuity of resources and activities. These approaches need to be understood and adopted by the relevant and appropriate institutions in the various countries

(there are already some examples) and should serve to overcome and surpass difficulties linked to institutional compartmentalisation;

- The environmental approach embraces a large range of themes that cover ancient and recent information and data as well as data being used to consolidate relevant knowledge bases that have been sufficiently validated through interdisciplinary channels to serve as a reliable source when creating decision support products. But often, university traditions and structuring have favoured specialisation and reductionism that basically reject interdisciplinary and the systemic approach which is now making inroads, albeit too slowly and too hesitantly. The study of a disturbing effect must include all examples of synergy; this requires cooperation between disciplines in identifying and evaluating the biophysical and socio-economic factors that contribute to the disturbing effect.
- Long-term monitoring is based on simple variables that generate data which, in "calm periods" are of little interest due to dispersal or variation (terms so dear to statisticians) is slight. This is the case in arid climates, especially during the dry periods. Remember that many observatories started monitoring the area during a very dry period which is often considered as a period that does not need to be monitored since "we do not need to measure vegetation when nothing is growing". But in an observatory, for instance, where the phytomass or the plant cover is not measured because of the drought, the missing data cannot be validly replaced by a "zero" unless this figure has been obtained through actual measurement.
- As concerns the instruments and equipment for the permanent stations, since the observatories need sustainability, they need to be equipped with the mechanisms sufficiently robust to survive a harsh environment over extended periods of time. With this in mind, it is always wise to be dynamic by having alternative solutions in case some mechanism become unoperational or breaks down, e.g. for every sophisticated, automatic precipitations recorder there should be a simple, hardier rainfall totaliser at stand by.

Interpretation and comparability of data and results

The quality of the results depends on both the data (sampling) and data processing and interpretation, which in turn depends on data harmonisation. Harmonisation was one of the major concerns in the ROSELT/OSS approach that provided for harmonisation of data collection techniques or at least the definition of a base or reference line that could make results comparable. The following data interpretation problems illustrate the diversity of the problem:

- There is a real problem in using ancient data, namely, integrating them as a base for evaluating existing resources or integrating them in the diachronic approach which compares snapshot descriptions in order to evaluate change occurring during the period between the descriptions. Examples:
 - In the first case, certain data may be too old as was the case with the evaluation of the aptitude of the soils at Menzel Habib and the description of (soil) usages in the Niger observatories. This said, ancient data can be valid over time if changes are not too profound. Similarly, if recent data are not available, the existing data, albeit ancient, are the best tool for approximating a variable.
 - In the second case, descriptions are given in map form which is often based on different cartographic criteria, e.g. a diachronic analysis was made in the steppic Hautes Plaines du Sud-Oranais, (Algeria) on the basis of two land use maps made at an interval of thirty years. There seems to have been a major evolution in the physiognomic units. This was confirmed in other evaluations linked especially to degradation from overgrazing. But some changes seem exaggerated, e.g. the extension of the halophilic facies. This could be explained by the difference between interpretation procedures (readings) used in 2004 and map-making (criteria of definition) used in 1978. The 1978 maps used two or three dominant species to define a cartographic unit while the 2004 maps only considered the leading species. In 1978, in many halophilic facies, the species that was indicative of salinity was considered second among the dominant species, while the first could be a species that was not exclusive to saline environments (in this case it was *Lygeum spartum*). This approach was important in identifying the accepted zones of halophilic environments since these facies were distributed as a crown around the chotts. In 2004, on the other hand, by only focusing on the single most dominant species, (halophytic in this example), all expression of the transition zone was eliminated. The result was an important regression of the facies with *L. spartum*, a species that is sensitive to severe droughts but quick to regenerate, and, on the other hand, the surprising extension of halophilic formations. The resulting image could be the expression of a time bound situation connected to the drought years, acting in synergy with human pressure. This example also brings up the problem of the ecological interpretation of vegetation maps based on physiognomic criteria.
- Different authors and schools of thought have different conceptions and definitions for a given object, concept or process. This explains the importance of unifying the meaning of words or at least specifying definitions

used when explaining results. Thus the surface crust is usually considered as layers of "hardpan or "sealed crust" in the observatories in Tunisia and Algeria but can also be of biological origin. The latter type has been reported in the Niger observatories. These two types of crusting have different impacts on water infiltration, seed germination and erosion control (cf. Casenave & Valentin, 1988).

- The surface areas of the observatories are very different, as are the scales used in making evaluations, e.g. evaluations are made at a scale of 1/25,000 in the El Omayed observatory, and 1/200,000 in the Sud-Oranais observatory. In both cases, the right scales have been used. Differences of this magnitude require different approaches to accommodate the level of precision in studying objects, e.g. agricultural activities scattered over small decametric plots (such as dayates/depressions) are hard to evaluate at a scale of 1/200,000. Similarly, some results do not have the same significance, which further explains the difficulty of making multi-scale comparisons.
- In some observatories, e.g. El Omayed, Haddej-Bou Hedma and Oued Mird, some lands have been protected, which changes their dynamics. Monitoring, in this situation, brings up the problem of control plots. In an in situ ecology type of experiment, two groups or series that are homogeneous at the outset are used. One is the "control" and is not subjected to any "treatment". The same measurements are made in the two groups before and during the experiment. The hypothesis is that external factors affect the two groups identically and that, in fine, the difference of effect can be traced to the treatment. In the case of pastoral rangelands (grazed and non-grazed lands), if part of the lands were enclosed at some earlier time, their systems have already been transformed and may be very different, so they should be viewed as independent systems that must be treated separately. In other words, neither of the two can be used as a "control" in the dynamics monitoring procedure nor used in certain observatories.

Quality of scientific reports

A scientific report from one of the observatories refers to what is commonly called "grey literature", i.e. not appropriate for publication in an indexed journal. But it is often just as important because it reports on progress in monitoring and on trends in all the disciplines without requiring original science. Grey literature has to abide by a certain number of rules e.g. give the context of the problem; stipulate the conditions, time spans and locations of the observations and measurements; describe the methodology and source of data; present all the

results in a clear, complete manner, and, lastly, explain the interpretation concisely showing the relation to the preceding steps.

Scientific reports have respected these requirements, more or less. Without going into details and setting aside sampling errors and mistaken interpretations, certain reports are found wanting essentially for the following reasons:

- they do not have a complete table of contents and/or bibliography, and their structure lacks coherence,
- results are sometimes presented as graphs, without locations and sometimes even without details on the corresponding sites or even the observatories;
- although the aim is time-specific monitoring, in some cases the origin, dates and places of data procurement are not given, and the bibliographic data or results do not include the clear spatial and temporal information on origins that is needed to be able to compare results;
- the basic biophysical characteristics, such as climate, geomorphology, soils types, etc. that should be included in a report covering a whole work activity, are sometimes missing;
- certain concepts, viewed differently by different authors, are presented without specifying definitions used, e.g. the word 'diversity';
- certain interpretations should be backed by analyses that enable a more concise presentation of the dynamic results.

These remarks, obviously, do not apply to all the reports, but bring out the need for a standardised format.

Information circulation

One of the main aims or advantages of networking is the circulation of information and data under precise, organised ethical and deontological conditions. The problem is mainly on the nature and mode of functioning of the network. Most of the teams are composed of experienced university scientists or scientists still in training. Recent data are not immediately available and are often being finalised, processed or analysed prior to publication or to being defended as a thesis or dissertation which explains the delays in transferring data sets. This is especially true for the very time-consuming environmental research, especially in the countries around the Sahara.

The need to transfer data under conditions that respect the requirements listed above can be described in explicit terms in conventions that commit the teams or in guidelines for the networks.

Data circulation, dissemination and utilisation must be covered by a guarantee to respect deontological rules. This seems self-evident but is worth writing up in a charter or even in a precise and strict code. When information is disseminated through well regulated channels, it reaches the scientific community, whose judgement gives it added value with positive repercussions for the authors and the teams concerned.

Data are pooled and disseminated either directly from databases or indirectly through metadata. The LEIS and Mdweb information system, now on its way to becoming fully operational, offers both these possibilities.

5- Orientations and prospects

The preceding remarks show the importance of the work accomplished but also point to the road that still needs to be travelled to reach the goals assigned to long-term monitoring under ROSELT/OSS and the OSS approach. Without pretending to provide final solutions, through these channels, certain ideas that draw on results and conclusions from the scientific reports can be put forth to help orient the work.

Approaches

As mentioned above, the long-term environmental monitoring approach is singular in its routine sampling method. In other words:

- this mode of investigation usually does not generate much original data, and the only interpretations and results that may be relevant are for the medium- or the long-term, which is not very satisfactory for scientists anxious to have their work published;
- committing to this type of approach requires motivation inspired by experience and a lofty awareness of the scientific need for long-term monitoring in order to understand the dynamic mechanisms, be they regressive (degradation) or progressive (restoration);
- since this work is often done by interns, students and even scientists in training, the turnover rate for observation and monitoring teams is high, and furthermore, this type of work, whose results are often biased, requires regular calibration to ensure harmonised measurements;
- variables that are strongly affected by inter-annual rainfall variability are monitored regularly every month, season, or year. To ensure greater rationality it would be worthwhile adapting the measurement of this variability by also incorporating detailed investigations of the flora and vegetation during the medium to wet years, and the soils during the dry years.

To meet these requirements it may be worthwhile coupling the monitoring operations with the more detailed and varied short-term research programmes, preferably focusing on problems stemming from the interpretation of monitoring results as such. Examples can be found in the observatories, e.g. the work on the nature and dynamics of soil crust formation, which gives rise to many questions. Monitoring them through frequency measurements (linear recordings) is not enough. More elaborate tools can be installed to monitor the short-term dynamics of these surface layers and crusts in order to determine the nature (organisms, algae and/or lichens involved) and the mechanisms of the physical and biological formations, to carry out experiments to evaluate the role of these surface layers on infiltration, seed germination, erosion control and conversely, to assess the effects of enclosing lands and grazing on these layers. The short-term programmes should be organised at the subregional level in order to obtain a relatively broad view of the subject of study with a focus on possible future extensions.

Optimising results

Results are maximised mainly through two channels: publication (far too little) and decision-support products (teams recognise the need). Some teams are asking for supervision or support which could promote and strengthen group work and develop a spirit of sharing (information, experiences, and data) within a strict deontological framework.

There is a strong demand for decision supports capable of improving the evaluation of resources, (including their location, state and dynamics), the goal being to achieve sustainable resource management. The products now available, i.e. information on state and location, will become more operational as knowledge is built up. But it will be impossible to fulfil all demands. The paradigm "decision support" has turned into a necessity and is seen as an ethical dimension of science that has been revived because of the state of the biosphere and/or the related risks, but making it operational is not always easy (Todd, 1999; Matthies et al., 2007). Environmental decision support is the main tool for transferring scientific results and for communicating with, on the one hand, the stakeholders involved in decision-making and the introduction of regulations and laws (decision-makers) and the people involved in exploitation of the resources. Besides inherent difficulties related to the level of knowledge, there are numerous barriers to overcome with regard to:

- decision-making: preference should be given to defining a framework that incorporates all the measurements and recommendations at the subregional or regional levels and can have an effect on the state and dynamics of the arid ecosystems (NAP and SRAP for the rangelands, cropping lands, water

quality and vegetation cover); the integration of systemic approaches defined at the international level for the protection and sustainable management of environmental resources, and the implementation of evaluations based on the most simple and effective indicators of state to allow for comparisons at the subregional and regional level;

- communication: since there is an unavoidable overload of information, – due to an inherent characteristic of scientists – messages, models and other products should be simplified by giving the main outline without having to explain the details. It is often also necessary to recognise and express uncertainties, even failures in the evaluations and the choice of indicators.

Spatio-temporal scales

According to scientific reports from the observatories, results appear to be relatively heterogeneous. In many observatories, some of the results, at least in the beginning, were strongly marked by work already underway, thereby suggesting a certain "specialisation" of teams. Heterogeneity can be explained by differences in approaches of course, but it also is caused by differences in regional eco-climatic, geomorphic and socio-economic elements. This discrepancy can also be traced to environment-specific preoccupations connected to factors such as erosion, overgrazing and agricultural expansion. All these differences require different scales of work:

- Spatially, land surfaces can differ tremendously from one observatory to the next. This explains the difference in the scale of resource localisation, taken as a DSP, whose usefulness, thus, can be more or less great. A map, for instance, is a visual aid whose use in development efforts depends on the scale, which is specific and depends on what it is to represent, e.g. proneness to desertification, pastoral resources, or soil aptitude for cultivation. Regardless of theme or form the DSP, the variables and parameters need to be measured and expressed in terms of a representative sample that is appropriate for the problem under study and the actions proposed for the DSP (predictive model, diagnostic, definition of reference for restoration efforts, control actions).
- Concerning the time dimension, which is essential in long-term monitoring, it is important to remember two embedded scales, viz. the inter-annual fluctuations, which are relatively natural and reversible, and the long-term trends that lead to irreversible successions, such as desertification. The notion of irreversibility, of course, is very controversial. In this paper, "long term" means some 10 to 25 years (e.g. respectively Rabotnov, 1974 and Floret et al., 1987), just to give an idea of the approximate scope of a very complex

notion. Theoretically it is impossible to understand these two scales, i.e. fluctuations and successions, separately. Non-respect for this rule is probably the most important point of debate, often contention, on desertification. The last words in such debates are often that the world scientific community does not give enough recognition to certain results.

In temporal monitoring, it is important to respect the scale of variation of the variables by adapting the measurements to the rhythm of fluctuation of the parameter under study. Land use, for instance, can very well be monitored once every five years while biomass production should be recorded once a year, although protocols can be made lighter as more knowledge becomes available.

Certain variables, such as soil nitrogen and the related mechanisms (import/export) are sometimes extremely variable in space, even in a small area, and require many repetitions to be evaluated at a given instant. This makes it very costly to extract effective, functional indicators.

Trans-boundary vision

Since the subregional and regional approaches involve different teams and therefore often use different approaches, we need to remember the difficulties in comparing results and in assigning them a relative significance. This is where the harmonisation of approaches becomes vital, as can be seen from the following examples:

- One basic goal has been to measure the extent of degradation and desertification in the different observatories which, on the whole, has been done. But, as many authors purport, (e.g. Behnke & Kerven, 1994; Thomas et al., 1994; Davis, 2005; Herrmann & Hutchinson, 2005; Retzer, 2006), we need norms to be able to "speak the same language", in other words we need referenced metrics on the potential of the resources. This should first and foremost be reflected in information derived from measuring techniques and/or similar indicators. Thereupon, the brief is to find metrics (classification of habitats, indices to evaluate the state of resources and the performances of key functions of the ecosystems) that can contribute to standardising evaluations and formulating norms for making comparisons.
- Scientific documents need to be harmonised by creating a standard outline for scientific reports to present activities related to the problem of desertification or, in a more general manner, to long-term monitoring (see above).
- Methods, techniques and classifications need to be standardised whenever possible, failing which their precise references must be given so that a baseline

for comparing key indicators can be defined. This is important, for instance, for soil analyses and classification techniques. Certain soil types correspond to classifications that are no longer being used, in the old French system versions by FAO, USDA-NRCS and CPCS. Another example comes from the evaluation of the state of vegetation: different techniques generate considerably different results (cf. *Vegetation Guide, ROSELT/OSS CT1, 2007*). As a complementary resource, it would be very useful to adopt one of the simplest techniques (point quadrats) for all the observatories in order to have a common reference norm for plant cover and the parameters that can be derived from it, such as biomass, pastoral value, diversity index, etc.

- Recognition that desertification is a global change justified the introduction of an international convention, the CCD whose scope of intervention is focused on the arid regions, and more specifically, the arid regions of Africa. The link between ROSELT/OSS and the CCD, thus, is natural and focuses on desertification control and knowledge enhancement. Alongside desertification, which is a global phenomenon that embraces problems of both the environment and development, there is another link that is just as natural, the link with the international conventions on biodiversity and climate change.
- It is important to encourage ownership and integration of long-term monitoring in a context of environmental change at the national, regional and global levels (cf. global changes). Climate models show that extreme variation is a growing trend in climate change, which unarguably will accentuate the present phenomenon occurring in the arid zone (IPCC, 2007). Thus, despite growing familiarity with these mechanisms, the participating countries, on the one hand, need to take over long-term monitoring by institutionalising it as an absolute national requirement to ensure sustainable resource management and, on the other hand, need to join a regional or subregional system that can generate added value thanks to greater understanding and a broader, transboundary view. The long-term monitoring network should, by definition, be free of the constraints imposed by project-based operating methods since project irregularity is incompatible with sustainability.

ROSELT/OSS, the long-term monitoring network, has been operating for close to ten years. It has acquired a certain experience and lessons can be learned to improve its functioning and output. The need for long-term worldwide monitoring is essential from a scientific point of view (cf. LTER network). It also seems essential when we look at what is at stake as a result of expected environmental change (desertification, biodiversity, climate). This is evidenced by the very existence of networks such as ROSELT/OSS and ELTOSA (Environmental Long-Term

observatories of Southern Africa). International bodies and, increasingly, governments are becoming aware of these changes. The next challenge is not only to improve the performances of the existing ROSELT/OSS observatories but to intensify long-term monitoring by adding less cumbersome groups of observation stations since there are too few stations considering the diversity of environments and problems. The goal is to create a monitoring mechanism graduated into local, national (national environmental monitoring mechanisms), and subregional systems in order to capitalise information obtained at all levels and scales, without compromising the subsidiary principle. ROSELT/OSS should be a driving force in this movement and, with this in mind, should be granted sufficient resources to guarantee a performance level in keeping with its objectives.

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●●● ANNEXES

Annex 1

Summary of environmental observation, measuring and monitoring activities in ROSEIT/OSS observatories

Observatory	Timeframe	Approach	Mechanism	Inventory	Quantitative measurements	Data processed	Other measurements	Biodiversity (flora)	Biodiversity (wildlife)
El Omryed	Spring 2003-2004.	Diachronic monitoring 1980, 1992/93, 95, 96, 98 to 2000. + Validation existing data => regional data metabase.	Transect cutting through different environments in plot zones (plot area); + permanent plots. Protocol for measurements (number and size of plots); vary, depend on lineframes and measurements.	Floristic lists (perennials + annual percent of cover using the Abundance-Biomass Ranking Index) on 16 plot areas, annually as of 1999.	Recorded segments interspersed along two 200 m permanent lines, plot, coast, line, spec.	Floristic diversity + systematic composition + indices of alpha and beta diversity.	Measure phenology: height + reproductive effort + density + other parameters monitored in four permanent plots 10 x 10 m.	183 species: 113 perennials + 70 annuals; 41 families (14 Asteraceae perennials + 7 annuals); Perennials: 14 grasses, 52 herb, 32 subshrubs, 18 shrubs.	136c. series: 130 to 200 animals species with vital functions: pollinator species, detritivores, or paternity and/or protected species)
Mansel Habib	Series measurements in Spring 2004 and 2005.	Diachronic monitoring	19 stations: permanent plots.	Floristic list: presence or absence of species in Spring 2005.	Pair-quadrate technique: permanent lines (20m, 200 reading points); 3 to 5 per station depending on variability (11 to Hechir Snow); specific frequency contribution, state of surface.	Matrix similarity processed by stat. dendrogram (similarity of sites); indices alpha + beta diversity + equitability.	Flt measurements: density + pair lines: perennials (20 m); annuals (2 x 1 m); Phytomass: 4 4m plots per station (Spring 2004); 2005 too dry a year: production considered null.	2003/2004 surplus year: 89 sp incl. 49 perennials and 40 annuals. 2005 total deficit: 50 sp (38 perennials, 12 annuals). For all of observatory: 171 sp.	No information
Haddaj-Bou Hedma	Series measurements in Spring 2002, 2003, 2004, 2005.	Synchronic method + diachronic monitoring	4 zones functioning or protection zones: Z1, 21 yrs, Z11 11 yrs, Z11, 6 yrs + control zone five 9 groups; 24 transects; Z1: 5 Z11: 4, Z11: 9 Zcontrol: 6. Zone II: experience with Spring scarring 2003.	Floristic list: present or absent in Spring 2004 (plots on or off of permanent transects)	Pair-quadrate technique: permanent lines (20m, 200 reading points); 3 to 5 per group; SF CSP plant cover, state of surface	Matrix similarity processed by Stancer diversity indices + equitability.	Flt measurements: plant density related to perm. lines. Perennials 120 m ² . Annuals (2 x 1 m ²).	Number of species in Spring 2004-2005: Z1 100-37; Z11 93-48; Z11 65-32; Z1 69-56.	133 bird species, potentially 176 and 42 sp. observed according to inventories; 25 mammals, 27 reptiles from exhaustive; 4 amphibians; fish (fish-farming); invertebrates (opisthopteres, crustaceans, molluscs, insects); Population variation monitoring introduced.

Observatory	Timeline	Approach	Mechanism	Inventory	Quantitative measurements	Data processed	Other measurements	Biodiversity (flora)	Biodiversity (wildlife)
Qued'Had	Series of measurements: 27/12/2004 to 02/01/2005. Modification protocol of measure state of surface in 2005.	Comparison 2005 measures / over values calculated for 2000-2004; Modification protocol of measuring state of surface in 2005.	11 veg units + 55 perm. transects (4 lines); 3 km transects oriented according to agropastoral activity (decreasing values and cutting through main environments); Perm plots 10 m ² every 100 m.	Complete floristic reading transects + climatic heights and state of species (favored, uprooted, etc.).	Four quadrat technique; permanent lines (20m); 200 reading points; 3 to 5 per formation; F5; CSP; plant cover, state of surface	Floristic richness.	Phytomass measurement (from 27/12/2004 to 02/01/2005) near perm. lines. herbaceous + low woody using destructive method on 4 plots (10m x 10m); 157% of floristic catalogue (2004); Disappearance of therophytes in 2005 (= 57% of floristic catalogue of 2004); Acacia present state, regeneration, phytomass accessibility, florological state of vegetation in 2004.	In Spring 2004, 84 species of which 15 new; incl. Falcata (12 sp. incl. Mammali (12 sp. incl. rare endemic sp.); In January 2003, 72 species; In January 2005, 46 species with rare/threatened (14); Amphibians (14); 157% of floristic catalogue (2004); Disappearance of therophytes in 2005 (= 57% of floristic catalogue of 2004);	Mainly vertebrates in 2002; 68 sp. birds (85% of protected list); Mammals (12 sp. incl. rare endemic sp.); Reptiles (12 incl. new); Amphibians (14); Avifauna monitoring 2005: 3 new sp.
Isougaï	2001 demarcate, Veg. units, local photos (1987) D1; Sogho; cores-podiceps veg; pedomorpho. units; 2004 phyt. ecol. invent.	Diachronic monitoring 2001 et 2005; phytocological recordings (flor. list + ab-don. samples, installed).	Permanent transects.	Flora and vegetation soils	Height, plant cover.	Processing in tables.		Floristic list per unit. Total: 71 sp. (1 row sp.; 30 form. 31 chromophytes and macrophanerophytes, 4 phanerophytes, 4 geophytes, 6 hemicytrophyles, 26 therophytes.	No information.
Steppes des Hautes Plaines	Field between 2001 and 2005.	Synchronic method + diachronic monitoring: 2004 vs 1978; Pilot site El Badi; 2004 vs 1978; Triangular site Mechtia - Ben Khalil - Naama; 2003 vs 1980-84.	3 sites: El Badi; 5 floristic ensembles; Rogassa; 9 groups + 10 facies, transect in relations to enclosed lands; Badi El Mar; 5 large groups + 16 facies; 320 phytoccol. readings pinpointed on map.	Complete floristic reading.	Point quadrat technique; lines coupled with part of readings; plant cover, state of surface.	Floristic richness, systematic biological composition.	About 40 complete phytocological readings with phytomass measurement and lines.	507 sp (234 genres, 46 families); Asteroceae = 48; 6 families with over 10 genres (Genetic code: 46%, Medit. elements (52%), Solonchobiers (23%), Therophytes (47.3%); Chamaephytes (23%); Hemicytrophyles (17%);	No information.

Observatory	Timeframe	Approach	Mechanism	Inventory	Quantitative measurements	Data processed	Other measurements	Biodiversity (flora)	Biodiversity (wildlife)
Felo	Investigations 2003-2005 following preliminary phase 1995-2000 and 2000-2002 (land cover map + general characterisation)	land use monitoring 1 time / 5 yrs at most	15 stations (Felo Sud), stations non-identified in Felo Station 4000m ²	Floristic inventory of main species	Forum, woody plants (diam, height), leaf prod, regeneration, physio status, Herbaceous veg: 3 transects (perm. lines, 50m/100points), Herbaceous prod. (9 samples)				No information.
Ribbia Sica	Oct/Nov 2005	Observations and measurements on erosion in 1-ha plots (Gardis) after each rain spell.	5x5m plots depending on elevation gradient	Flora and fauna inventory (28 seedlings or sites)	Evaluation abundance veg. sp. using Braun-Blanquet coefficient	Phytosociological method to determine groups.	Phytomass on 5x5m plots to evaluate fodder (Quality index 0-10). State of surface.	60 plant sp. inventoried (2005) of which 1/3rd phanerophytes.	38 sp. vertebrates out of 57 already inventoried. Birds (33 sp.), mammals, reptiles and amphibians.
Torodi-Tondlandor-Dandombou	No information.	Monitoring of land utilisation, hydrology (land area of different units) and vegetation.	Phyto reading	Floristic description using Braun-Blanquet method	Abundance-dom. of species, Density of stems/stems of woody sp. per circumference class, production of exploitable timber.	Community diversity indices; correlation regression; multivariate analysis.	Indication of state of surface (algal crust)	73 sp. inventoried in protected site.	No information.
Bouam	Vegetation (2002-2003).	Sanding (linagery, observation, measuring flows through sand trapping).	Sanding (5 units, EW zoning), plant cover (64 greenfield), Veg and env. monitoring (27 sites in 3 groups A, B, R; herb. veg.: 100m transect, evaluation by m ² of cover/sat), woody veg.: group of 8 sites (Bambal	Floristic inventory (herbaceous, woody veg.)	4 perm. lines per site (50m/200m on 1000 m transect); Point-quadrat technique; specific frequencies; biomass indirect or through density 12 plots per transect; Density of woody plants per circum. regeneration class, intensity.			Floristic richness: 52 sp. inventories with 81% herbaceous incl. 16 poaceae, 26 phorbies 16 sp. Woody (all Sud-Haouss) incl 4 of Acacia genus.	No information.

Annex 2

Summary of socio-economic monitoring in ROSEIT/OSS observatories

Observatory	Sample	land use	livestock practices (subsistence/intensive)	Sedentarization	Cattle	Stocking rate	Animal feed
El Omryed	435 households representing 6 tribes. Questionnaires + interviews with head of family, 1997 data.	livestock, tree crops (olive, fig), raited crops (barley).	Extensive rearing, sheep + goats + donkeys (for transport) poor le transport.	Increased grazing pressure caused by reduced rangeland	1985: 43 sheep and 118 goats	Increased pressure on rangelands. => rangeland degradation.	Dryland barley crop with secondary use as regime complement for sheep and goats (khar and seed)
Menzel Habib	309 households, 908 variables, Questionnaires	livestock, agricultural, tree crops	Sheep + goat rearing. High level of sedentarization, little herd movement.	Gradual sedentarization beginning 20th c.	Head = 28 sheep + 10 goats (milk for family). Very few camels and cattle. Chickens + rabbits in < 1/4 of farms.	Average stocking rate = 1.2 head per ha and 0.75 head per ha (w/out transhumant animals); Rate 6 times too high.	Feed supplements as needed
Hoddey-Bou Hadimo	478 farms out of 2038. Questionnaires. Beg July to Sept 2004	6% agro-pastoralists: 23% farmers (oweds, tree crops); 5% livestock producers.	Sheep + goat rearing. 18% transhumant herders.	1990s, privatization of rangelands + planted for tree crops => Sedentarization intensified. 85% of herds use same rangelands.	Head = 16 sheep + 10 goats. Very few camels (2) and cattle (2 farms have 4 head). 31% households raise chickens.	Variable	Feed supplements = 90% concentrates + by-products from animal crops.
Oued Mid	36 farms / 145 Classes: herders: d 1, n=11; d 2, n=18; d 3, n=7. Questionnaires + livestock count + interviews with resource persons, January 2003.	livestock, agro-pastoralists / farmers whose relative importance depends on the geomorphological situation	2 systems: nomad + sedentary (many practices dictated by investment capacity + family labour availability).	Gradual sedentarization: 16 nomadic family farms. Problem with drawdown of vatable lands few years, sedentarization slowed down.	Total herd in sample: 196 uz sheep + 428 uz goats; negligible number of cattle	Variable	Needs of sedentary pastoral livestock covered by: fodder production = 24.16 % + purchases = 13.55% + rangeland.
Isougui	Platin. discussions: 3/70 livestock producers, 10 farmers in the plains, 6 in the mountains, 10 agro-pastoralists in Saglio. By survey 2004-05.	Agriculture; pastoralism; transhumant livestock production; timber and other.	Sedentary sheep + goat rearing. Semi-sedentary and extensive transhumance (winter crop period on plateau; summer pasture in mountains; movement to distant rangelands: Bil, Scars, Tafilalet etc.	Gradual sedentarization over last 50 years.	Sed. list prod. 8 man 15-10 head/household; herding 1/2 sheep/goats, 160 head/household; transhumant: over/herder 160 sheep, 140 goats.	Stocking rate rising because of land turned over for agriculture. Agdal practice in mountains (land rested).	Fodder on rangelands, cultivated fodder, other.
Seppes des Hautes Plaines	50 herders based on list supplied by local authorities. Survey with livestock producers.	Mainly sheep + goat rearing, raited agriculture (barley).	Herding method: extensive (n=20); Semi-nomadic transhumance (n=12); Semi-nomad (n=200) (14% live in tents)	Important effects of sedentarization = 80% of pop. have permanent housing (14% live in tents)	Sheep rearing: total flock of 9260 head, 185.2 head per stock farmer	Stocking rate: 3 to 4 times about in balance rals.	Feed supplement = 61.5% feed requirements: concentrates + cereal crop products and by-products (barley, straw, seeds).

Observatory	Sample	Land use	Livestock practices (intensive/intensive)	Sedentarization	Cattle	Stocking rate	Animal feed
Felo (Ouarzghatt)	183 localities - 2004 questionnaire; organisation, background, inventory, land tenure; 2005 questionnaire	Agric: 65%; livestock 21%; trade/artisanat 8% other	transhumance, mainly sheep (23% of livestock); improve fecundity, variable distance from low km to several hundred). Access to lands subject to conditions. Watering wells + forages (68%), temp ponds 31%.	No trend observed.	Com: Overallly: 56,228 cat., 95820 sheep, 44063 goats, 6000 horses and donkeys.	3.5 IU /km ² (balanced stocking rate) + transhumant animals + camels (overstocking). Per IIA: 0.6 cattle, 2.3 sheep and goats. In time problem of feeding animals.	Supplements: agrics by products (88%) generally local, wild crops (28%), 81% in dry season.
Ribera Seco	Survey with 1703 persons; 2005 questionnaire (random sample, comprehensive survey of population)	Agriculture, livestock production	Sedentary, small-scale family livestock prod.	Population mainly sedentary	Mainly pigs, goats and poultry.	No information	Agricultural byproducts + natural vegetation
Torad; Tendilandia; Dandantou	Bibliographic information (Gallais, 1975)	Rainfed crops, livestock production	Extensive livestock production. Herds entrusted to Fulani in rainy season (far distant transhumance); movement on plateau and Dald (short transhumance).	No trend observed.	Cattle, sheep and goats.	No information	No information
Bourem	2 villages Arma and Songhoy respect. (Bamba Island and Kermachoy) + nomadic zone around pastoral well (Iiamankori). Survey on land tenure: agricultural, pastoral, water, forest.	Pastoral: lands and wells subjected to customary law; agriculture	Extensive livestock production.	No trend reported	148000 i, 53000 comprising 1/3 cattle, 1/3 sheep-goats, 1/3 camels/horses/donkeys	Stocking rate reported to be excessive but not evaluated mainly along river.	No information

Observatory	Agricultural practices	Production / land area	Status of lands, ownership	Other uses (plants, medicinal plants, etc.)	Trends (changes in land use)	Revenue and sources	Currency
El Omayed	Dominance of irrigated tree cropping (fig, tree, olive tree) = 4/5th of cultivated land + dryland cereal cropping	Cereal crop harvested about once every 5 yrs; 2 q/ha of grain; 3.5-5 q/ha straw. 2.4 pcks/lame; aver. 5.37 ha/pck	land ownership - rights conditions by development of irrigated tree crops	82 species (22 animals + 60 plants) = 52% of total domestic economic use: forage, fuel, medicinal, food/feed, other	land livestock count going down. More tree crops (1/5th of cultivated land). Rapid extension to detriment of good cereal lands which was detrimental to best rangelands (main problem: water supply)/ Special co-operation + tourism infra-structure along coast.	No information	1 Egyptian pound (LE) = 0.13 €
Menzal Habb	Revised agriculture = 93%; Annual crops = 52% of farms for last 100 years; irrigation recent (40 yrs) = 1%. Tree crops (olive = 52%) = 40% of farmlands.	Cereal yield: 3.2 q/ha; Olives 1kg/tree per year; dry: 2; aver. 29; vert 63. 23 ha/exploitation in 2.3 pcks; 70% of farms < 20 ha.	Privatization of communal lands as of 1970s (pck); Privatisation = 70% of lands. Mode of ownership = inheritance (97%).	Frequent recourse to medicinal plants.	Extension agric. lowlands then to foothills (+ hydroal installations) then rangelands; loss of best rangelands.	Aver. annual income/household: 3801 DT. Livestock (37%): dryland agric. (11%); irrigated agric. = 5%; extra-agric. (40%): trade, workless, artisanal, state aid and subsidies.	1 Tunisian Dinar DT = 0.6 €
HL - Bou Hedra	Revised agriculture dominates = 97% of farms. Cereal crops (wheat + barley) in scattered plots; Tree crops (olive and almonds) = 45% of private lands for each of the two. Irrigated crops (peas, horse beans) = 1%.	Tree crops = 72%; home consumption + 10% commerce. 18% > 20 ha in 2.3 pcks on average	Family lands = 1.4 ha / 7 heirs; Communal lands = 120 ha; 41 heirs; Private lands = 53% of farms = 5-20 ha; Ownership: 97% through inheritance.	Wood removed for household use, still sizeable despite introduction of biomass gas, and new regulations.	Decline in transhumance connected to more cropping (handicap for displacement) and mechanisation (tractors and trucks); => decline in camel production (1 or 2 head still in a few farms).	Aver. annual income/household: 3430 DT; agric. 1283 DT; Livestock: 1038 DT; Extra agric. 1828DT. Variation coef. = 83% to 113%.	1 Tunisian Dinar DT = 0.6 €
Oued M'yd	Agriculture that can be irrigated is subsistence crops, except for beans and some types of tree crops.	No information	Communal rangelands belonging to local tribes; access to outsiders impossible. But intra and inter ethnic relations and utilisation rules are changing.	Wood removed for household use: = 0.5 kg woody material per inhab./day = 160 tonnes/yr.	land intensification (at pck); dev of sedentary (at pck) Stock-raising (at pck) in 1999; 16 in 2004). Decline on rangelands (goats 1-47%, sheep 1-30% and esp. camels); appearance of cattle and D'man and D'ra sheep (more sedentary); more feed supplements.	Pack: margin seed lot (DH/12/yr): 313 (sheep) at 300 goats; Agric. margin: DH/ha: 10,730 for cosmetic items, results negative. 2,356 and 2278 DH/ha for common wheat and barley.	1 Moroccan Dirham (DH) = 0.09 €

Observatory	Agricultural practices	Production / land area	Status of lands, ownership	Other uses (plants, medicinal plants, etc.)	Trends (changes in land use)	Revenue and sources	Currency
knouga	Intensive in the plains (Oued Doudé); tree crops, cereals, alfalfa (forage for sheep).	232 ha total, 76% of the farms; < 0.5 ha.	Communal (Troyaga land exploited as usufruct, terrace 'lgan' or 'Asuf' terrace has 'halk' status (private, family)).	Oilseeds for firewood and artisanal (250 persons wild picking)	Recourse to agriculture for remainder land. producers. Accelerated sedimentation since 1980, semi-sedentary land prod. Agriculture taking over winter rangelands and consuming water for agric.	Diversification income diversification when climate unfavorable (trade, transport, tourist guide, etc.).	1 Moroccan Dirham (DH) = 0.09 €
Steppes Hautes Plaines	Rainfed crops, cereals (2/3 barley)	Cereals: yield < 2 q/ha lands given to agriculture = 176 ha, Aver. = 3.3 ha/livestock producer Pick 11 to 40 ha on average	Legal status of rangelands = arch type (halk). Free exploitation if not interfering with cropping lands.	(Minor importance): woody plants, medicinal plants, fodder.	Peasant land, prod. declining. Pastoralism < 1/4 working pop. in the steppes (1998 census); > 3/4 incl. agriculturists in 1966.	Mainly land production, trade in water and animal feed. Incentive for producers with 1000-200 head of cattle, or recycling former land producers	1 Algerian Dinar (DA) = 0.01 €
Felo (Ouatkhaki)	Rainfed crops: 58% millet, 33% groundnut + cowpea watermelon. Fallow: 32% of plots (of which 66% < 0.5ha), crop rotation never (55%, always 18%)	Average yield per ha (1992-2001): Groundnuts 5.9 q, millet 4.9 q, cowpea 5.0 q, low (little input), c.amps < 1 ha (2.4%), 1-3ha (35%), 3-6 ha (2.8%), > 6ha (13%)	Iron 32%, cleaning 19%, other (light, inheritance, etc.)	Timber (Balantés, Nèzèr), human and animal food (Coccoloba, A. radiana, Balantés, Jujube, Boobab, etc.)	No tendency reported	1500000 CFA/fr per capita. Not profitable activity: agriculture (44%) then livestock (38%) + emigration + other	100 F.CFA = 0.12 €
Ribeira Seca	Rainfed crops on slopes and plateau (over 7 ha zone 1) and irrigated in valley bottom (over 0.24 ha zone 2)	Rainfed crops: mainly maize, cowpea, beans Irrigated agriculture: market crops, bananas, groundnuts, sugar cane. Rainfed agriculture: over 10 ha per plot; irrigated agric.: 0.2-0.5 ha per plot.	Private plot	Firewood: 300 to 600 kg/fr/household	No tendency reported	No information	1 Escudo (ECV) = 0.006 €
Toral-lond-lond-Dandlombou	Mainly rainfed subsistence crops. Irrigated or recession crops in dry season.	No information	No information	Firewood, also for sale.	No tendency reported	No information	100 F.CFA = 0.12 €
Bourem	No information	No information	Detailed study on land tenure.	Mainly firewood: over-exploitation of woody species near river. Soil for livestock management through local agreements, conflicts reported.	No tendency reported	No information	100 F.CFA = 0.12 €

●●● ROSELT/OSS NETWORK PARTNERS

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The long term ecological surveillance observatoires network (Réseau d'observatoires de surveillance écologique à long terme, ROSELT/OSS) of the Sahara and Sahel Observatory (OSS) consists of a cluster of observatories which span circum-Saharan Africa and share a common focus on the issue of desertification. Since its inception, the network has been addressing the challenge of improving the collective knowledge on desertification; a scourge that has complex linkages with the issues of biodiversity and climate change.

Over the last ten years, OSS has put in place standardised protocols of data collection and processing in the circum-Sahara with a view to apprehending the trends characterising the evolution of the ROSELT/OSS observatories' ecological and socio-economic systems. In this part of Africa, where rainfall decrease is chronic in the Sahel and spreading to North Africa, population growth and land use change—due to overgrazing or the conversion of rangelands into croplands—have adverse impacts on the environment. In addition, sand encroachment constitutes a serious threat to irrigated farmland. Biodiversity is equally affected, as several species face the danger of extinction due to human activities.

In the south of the Sahara, natural resource depletion is often among the causes for migration towards the zones where climate and life conditions are more favourable. This forced displacement is significantly less severe in the north of the Sahara where policies put in place by governments in the sub-region encourage sedentary lifestyles.

Based on the scientific reports of the ROSELT/OSS observatories, this publication provides an overview of the data management systems and the decision-support tools developed across the ROSELT/OSS network. It also highlights difficulties pertaining to environmental surveillance in North and West Africa.

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