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Potential Impacts of Climate Change on Soil Fauna: Case of the Xero-Mediterranean Omayed Biosphere Reserve (OBR), Egypt

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ABSTRACT

The area of the Omayed Biosphere Reserve on the northwestern Mediterranean coast of Egypt, at about 80 kms west of Alexandria, was and still is a site of long-term ecological research (LTER) on almost all ecosystem components since 1974. Inevitably, prospects of the expected climate change have imposed themselves on the approaches of this research. While changes in vegetative cover can be relatively easy to monitor, the impacts on soil fauna are more difficult to monitor, or to predict their outcome. Yet, the wealth of information on this fauna is poised to allow a preliminary assessment of such an outcome. Since the biotopes of the area run in linear alignment parallel to the coast, and that rainfall decreases sharply from 150 mm/yr at the coast to 30 mm/yr only 80 kms inland, it is too easy to predict that innermost soil fauna populations will gradually replace those in its near proximity, with decreasing rainfall and increasing temperatures. The complexity of the multitude of factors involved precludes such a simple conclusion. Different species have different capabilities of adaptation to higher temperatures and less humidity. Therefore it is not to be expected that the whole biocoenoses will migrate in an orderly fashion, as if they were regiments in an army. Hence not only species will be arranged in different communities, but also the equilibrium between the main three functional groups of soil fauna (detritivores, herbivores, and carnivores), will be much disturbed.

1. INTRODUCTION

The distribution of species in an ecosystem can be ascribed to the sum total of interactions of several factors. Several recent laboratory studies have been carried out on the impact of climatic conditions on soil fauna (*e.g*. Coûteaux and Bolger 2000, Kardol *et al.* 2011, Blankinship *et al*. 2011[1]), while some others are merely speculative. Very few were conducted at a field scale experiment (*e.g.,* Andersen 2010). These studies, however, are still unable to give concrete answers to what impacts might be expected (*e.g*. Churchman 2010, Pritchard 2011).

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[1] http://www.springerlink.com/content/r6u2584xw468nn00/

The Omayed Biosphere Reserve (Fig. 1) is located in the western Mediterranean coastal region of Egypt (29° 00' - 29° 18' E and 30° 52' - 20° 38' N). It extends about 30 km along the Mediterranean coast from west El-Hammam to El-Alamein with a width of 23.5 km to the south. Its N-S landscape is differentiated into a northern coastal plain and a southern inland plateau. The coastal plain is characterized by alternating ridges and depressions running parallel to the coast in E-W direction. This physiographic variation leads to the distinction of 6 main types of ecosystems (Salem 2008), as given in Table 1.

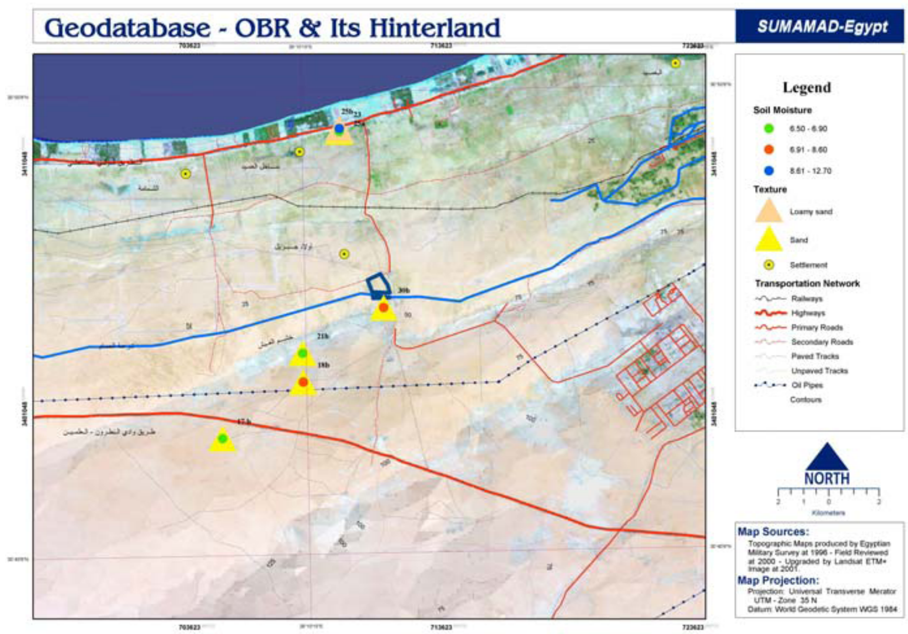

Fig. 1 - Location and landscape of the Omayed BR (OBR), (after Salem 2008)

In the xero-Mediterranean climate of the various habitats of the north-western coastal land of Egypt, the amount of data so far available from the long-term studies carried out at the Omayed Biosphere Reserve since 1974 (Ayyad and Ghabbour 1977, Salem 2007/2008 and 2008, Abdel-Razik 2008), seems sufficient to corroborate attempting to make some preliminary conclusions on the singular or combined effects of these factors on species presence/absence and on population size, as well as ratios of functional groups of soil fauna. Results of these studies (Hanna *et al.* in press), show that more aridity and increasing temperatures, from north to south, give lower population sizes and different ratios of the three main functional groups of soil fauna (detritivores, herbivores, and carnivores). Diversity of soil fauna can be more clearly different at the micro-ecosystem level rather than the regional level, even under the same climatic regime. The regional biodiversity of soil fauna in the same climatic zone of the Mediterranean coast of Egypt showed that the northwestern region (Gharbaniat, Omayed, and the Mariut Frontal Plain), is more diverse than in the middle Delta coast region (Balteem), or the northeastern region of the Sinai Peninsula (Rafah). We also note that the fauna of the northwestern region can be distinguished into three coastal bands: (1) the attenuated climate at Gharbaniat, (2) the accentuated band represented by the fauna of the Omayed Biosphere Reserve, and (3) the band, further south, designated as the hyper-accentuated band, represented by the fauna of the Mariut Frontal Plain. This differentiation can be attributed to the different ecological factors prevailing in these regions, such as the level of rainfall (amount and seasonality), temperature, and other climatic factors (mainly air relative humidity and dewfall), as well as soil texture and vegetation types. Additionally, on the regional level, the diversity of soil fauna may be affected by the degree of human interference, such as agricultural practices. New species invaded the coastal deserts when irrigation water was brought to these lands for agricultural reclamation. Within a certain number of years, the reclaimed desert land may become so similar to "old" Delta land, that the process may be called "Deltaisation". This process may take from 5 to 20 years, depending on intensity of human effort applied in land use (irrigation water, ploughing, crop varieties, fertilizers, and pesticides). It is not a surprise that agricultural pests, such as the mole-cricket and some Lepidoptera, are attracted to these "new" lands. Besides, other useful species may be brought in inadvertently, such as earthworms.

Given these facts, it would be reasonably expected that, in general terms, less rainfall and higher temperatures may result in disappearance of the soil fauna biocoenoses of the wetter coastal strip (the littoral sand dunes at Gharbaniat), and its replacement by the soil fauna of the more inland OBR, followed by the fauna of the Frontal Plain that would occupy the OBR, and the almost complete disappearance of soil fauna populations from the more southern Mariut Frontal Plain, making it as devoid of soil fauna as is the rest of Egypt's Western Desert.

But is it really as simple as that? What is more important for soil fauna will be changes in climate and soil conditions in the coastal Mediterranean zone of Egypt, characterized by a winter rainfall regime (100-200 mm/yr) and mild winter temperatures. The present paper tries to examine the potential impacts of a probable climate change towards more warmth and aridity, on soil fauna populations in this zone, as well as in the middle and eastern parts of the Egyptian Mediterranean coast, which enjoy the best climate in Egypt, and hence the richest and most diverse soil fauna in the country.

1.1 PRESENT STATE OF KNOWLEDGE OF THE BIODIVERSITY OF SOIL FAUNA IN THE OBR REGION

According to Salem (2007/2008), the Omayed area receives most of the rainfall in winter. It receives about 150 mm/year. The formation and persistence of soil cover in the El Omayed area are strongly influenced by the arid climate. The scarcity of water for reactions within the soil and for the leaching of soluble components from the soil itself restricts the extent of soil formation processes. All soils in the area are considered to be very young and immature, and as highly influenced by the geological and geomorphological conditions of their formation. These soils are sandy loam to sandy clay loam and often at least 1m deep; salinity problems are frequent in the lowest lying areas. Generally, the chemical analysis of these soils indicates that they are characterized by low salt content. Organic matter and total nitrogen contents are relatively higher in the cultivated (olives and figs) soils than in unmanipulated areas, calcium carbonate is generally very high in the coastal areas.

After the extension of a supplementary irrigation canal from the Nile, the extent of irrigated areas of Omayed have increased to about 8%. After being sedentary, together with population growth, overuse of water resources, overgrazing and uprooting of indigenous vegetation, climate change, and other political and social forces, there has been an increased pressure on land resources that affected its performance and provision of goods and services.

The components of ecosystems of the northwestern Mediterranean coastal land of Egypt, within which is situated the Omayed Biosphere Reserve (OBR), were intensively studied in the period 1974-1983 under the SAMDENE Project (Ayyad and Ghabbour 1977). Research since 1983 has been concentrated on management and community services (Salem 2008). One of those ecosystem components that were studied was soil fauna populations (see list of references). Studies of these populations were also carried out in Balteem (Delta coast) and Rafah (North Sinai coast), as well as in many other regions in Egypt. Data obtained from these studies, comprising differentiation of biotopes and analyses of functional groups of the soil fauna, were treated by special statistical techniques to discern their relationships (Hanna *et al*., in press). The present report is largely based on the findings of that analysis.

At the Omayed BR region, soil fauna populations were studied in these biotopes:

1. Littoral sand dunes at Gharbaniat, immediately adjacent to the shoreline, with 180-200 mm/year rainfall
2. Non-saline depression, within the OBR, about 10 kms south of the coast, with 100-180 mm/year rainfall,
3. The Mariut Frontal Plain, an open desert area south of the OBR, 10-50 kms south of the coast, with 50-100 mm/year rainfall,
4. Dry farmed fields in the littoral (barley) and non-saline depression (almonds and figs), at Burg El-Arab, and
5. Irrigated fields of maize and fruit trees, also at Burg El-Arab, at the level of the non-saline depression.

Ayyad *et al*. (1984) had classified the desert climate of the Mediterranean desert of Egypt into two classes: an attenuated one on the littoral strip and an accentuated class further south. This classification was taken up by Ayyad and Ghabbour (1986) for the climate of the entire hot deserts of Egypt and the Sudan. According to this classification, the Gharbaniat site belongs to the "attenuated xero-Mediterranean class" while the OBR site belongs to the "accentuated xero-Mediterranean class". We propose here a further class that we call "the hyper-accentuated xero-Mediterranean class" represented by the Mariut Frontal Plain area, and similarly situated areas all along the Mediterranean coast.

Table 1 shows the soil fauna species and taxa that were found to be common for the various regions of the Mediterranean coastal land of Egypt listed above (*i.e*., including the NW, the middle (Balteem), and the NE (Rafah) regions).

Table 1: Soil fauna species and taxa common for the various regions of the Mediterranean coastal land of Egypt.

1 - Species of soil fauna common in all coastal desert sites Isopoda, Spiders, Scorpions, Ticks, Geophilomorpha, Thysanura, the "sand roach" *Heterogamia syriaca* (Dictyoptera), Mantidae, Antlions, Formicidae, "other Hymenoptra", Diptera, Lepidoptera, Tenebrionidae, Scarabaeidae, Carabidae
2 - Species of soil fauna common in littoral sand dunes under 180-200 mm/yr rainfall (Attenuated climate: Gharbaniat, Baltim and Rafah): Pseudoscorpions, Scolopendra, Heteroptera, Sphecidae, Coccinellidae, Curculionidae
3 - Species of soil fauna common in coastal desert sites at 10-20 km from coast, under 100-180 mm/yr rainfall (Accentuated climate: Omayed Biosphere Reserve): Snails, Scolopendra, Heteroptera, Sphecidae, Curculionidae
4 - Species of soil fauna common in coastal desert sites at 20-80 km from coast, under 50-100 mm/yr rainfall (Hyper-Accentuated climate: Mariut Frontal Plain): Galeodidae, Heteroptera
5 - Species of soil fauna common in coastal desert sites under dry farming (Burg El-Arab): Earthworms, Gryllidae, "Other" Orthoptera*, Dermaptera, Homoptera, Hemiptera, Curculionidae (weavels)
6 - Species of soil fauna common in coastal desert sites under irrigated farming (Burg El-Arab): Earthworms, Gryllotalpidae, "Other" Orthoptera*, Dermaptera, Hemiptera

* "Other" Orthoptera include Mantidae.

Table 2 shows the differentiation of this fauna to functional groups of soil fauna populations in the various regions of the Mediterranean coastal land of Egypt. The functional groups are detritivores (litter feeders), which are usually the majority of soil fauna populations, herbivores (feeding on living plant material), and carnivores (feeding on both and among themselves).

Table 2: Functional groups of soil fauna in the various regions of the various regions of the Mediterranean coastal land of Egypt.

Detritivores	Herbivores	Carnivores
Earthworms	Snails	Spiders
Snails	Gryllotalpidae	Scorpions
Isopoda	“Other” Orthoptera	Galeodidae
Thysanura	Heteroptera	Pseudoscorpions
Gryllidae	Homoptera	Ticks
“Other” Orthoptera	Hemiptera	Geophilomorpha
Dictyoptera	Lepidoptera	Scolopendra
Dermaptera	Curculionidae	Mantidae
Sphecidae	“Other”species*	Antlions
Formicidae		Carabidae
“Other” Hymenoptera		Coccinellidae
Diptera		
Tenebrionidae		
Scarabaeidae		
“Other”species*		

* A small number of unidentified species was found in the Mariut Frontal Plain, Balteem, and Rafah. They are named here: “Other” species. They comprise both detritivores and herbivores.

Table 3 shows the percentages of individuals of functional groups of soil fauna taxa in the Mediterranean coastal land of Egypt, in the OBR area.

Table 3: Percentages of individuals of functional groups of soil fauna taxa in the OBR area (after S. Hanna *et al*. (unpublished)).

Sites	Herbivores %	Detritivores %	Carnivores %
Gharbaniat & Mariut Frontal Plain	2	92	6
Omayed BR	3	88	10
Omayed BR enclosure	13	61	26
Dry farming, Burg El-Arab	15	80	6
Irrigated farming, Burg El-Arab	12	81	7
Balteem	1	87	12
Rafah	4	89	7

Note the predominance of detritivores.

Table 4 shows the number of taxon groups (S), the number of individuals/unit area (N), the intra-habitat diversity (H_a), the inter-habitats diversity (H_b), the relative intra-habitat diversity (H_p %) and the Evenness ($J' = H_a / H_{max}$) in different sites the OBR area of Egypt.

Table 4: Number of taxon groups (S), number of individuals/unit area (N), intra-habitat diversity (H_a), inter-habitats diversity (H_b), relative intra-habitat diversity (H_p %) and Evenness ($J' = H_a / H_{max}$) in different sites of the OBR area (after S. Hanna *et al*., in press).

Site	S	N	(H_a)	(H_b)	(H_p %)	Simpson Index	($J' = H_a / H_{max}$)
Gharbaniat	17	19	1.67	1.05	96	0.32	0.59
Omayed BR	17	14	1.77	0.99	101	0.26	0.62
Omayed BR Enclosure	17	39	2.15	0.82	123	0.15	0.76
Mariut Frontal Plain	17	57	2.14	0.82	122	0.16	0.73
Dry-Farming, Burg El-Arab	20	24	2.21	0.79	126	0.16	0.74
Irrigated farming, *ditto*	14	47	1.66	1.06	95	0.27	0.63
Balteem	6	15	1.22	1.44	70	0.36	0.68
Rafah	8	6	0.99	1.77	56	0.55	0.48

The data on soil fauna populations in the present study belong to a wide range of sites and varying degrees of land use intensity. This variation in geographical-ecological zones in Egypt and in land use practices impacted on soil fauna density and, in consequence, species diversity and biological functional groups (herbivores, carnivores and detritivores). In this study, the dominant functional group in the grazing lands of the western coastal Mediterranean (Omayed and Gharbaniat) is the detritivores (Dictyoptera, Tenebrionidae and Scarabaeidae), constituting 87% of the population. Similar results are obtained in the dry farming agriculture areas in the same region. Land use practices and patterns therefore do not have a major effect. In the irrigated desert ecosystems, changes in soil fauna groups did not show significant variation, except by replacement of some taxa by others, such as introduction of earthworms as major detritivores, through the introduction of Nile water and silt carrying earthworm cocoons. In this respect, earthworms in the irrigated desert agricultural areas constitute approximately the 32% of the total soil fauna population, while in the rainfed sites they constitute approximately only 2%.

1.2 THE REALITY OF CLIMATE CHANGE IN EGYPT

Fig. 2 after Domroes and El-Tantawy (2005), shows that the difference trends for air temperatures in the area of Alexandria was only about half a degree between 1971 and 1999, while in Aswan in the south, at the northern tip of Lake Nasser, average air temperatures has risen by 2 degrees Celsius for the same period. These differences show that at least in Egypt, the coastal regions are much less vulnerable to global warming than the inner desert regions.

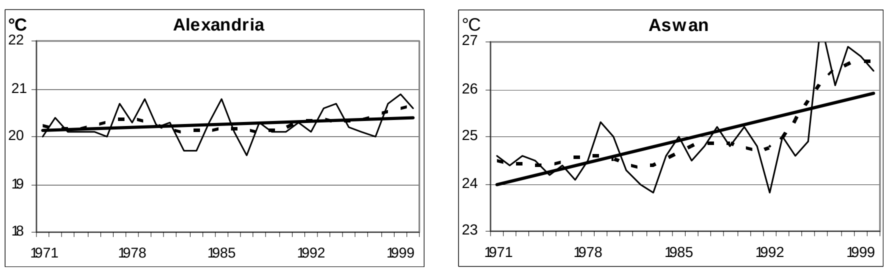

Fig. 2: Air temperature trends in Alexandria and Aswan climate stations, 1971-1999.

The amount of incoming radiation which is reflected from the earth (albedo) has an important bearing on the earth's response to climate change. The albedo of different surfaces varies with vegetation and cover. The following Table 5 shows the world distribution of the degree of the earth's reflective potential (the albedo). It can be seen that desert sand has the highest albedo (0.40), followed by grassland (0.25). The lowest albedo is from fresh asphalt (0.04).

Table 5: The albedo of different earth surfaces[2].

Surface Type	Range of Albedo	Surface Type	Range of Albedo
Fresh snow	0.80 to 0.90.	Bare soil	0.17
Old/melting snow	0.40 to 0.80	Coniferous forest	0.08 to 0.15
Desert sand	0.40	Worn asphalt	0.12
Grassland	0.25	Ocean	0.07 to 0.10
Tundra	0.20	Ocean ice	0.5–0.7
Deciduous trees	0.15 to 0.18	Fresh asphalt	0.04

[2] http://www.maximizingprogress.org/2008_02_01_archive.html

Aswan lies within the Great Sahara Desert, the earth's region with the highest reflective potential, which includes southern Egypt. This explains why global warming is more evident in Aswan than in Alexandria. Aswan area does not only suffer from an actual elevation of temperature from incoming solar energy, but receives, in addition, a substantial share of heat reflexion from the surrounding desert. Although Alexandria is not far from the desert, it probably enjoys the northern and northwestern winds, which attenuate the effect of the desert albedo.

Abdel-Razik (2008) gave a detailed account of trends in climate, soil parameters, and vegetation at the OBR between the 1948-1975 period and the year 2000. For climate, he found indication of a steady increase in the mean daily air temperature by 2-3° C, relative humidity10-15%, and annual rainfall 20-30 mm. Rainfall, on the other hand, showed a stepwise decrease below the long-term average during the winter seasons, starting in 1995, and a continuous increase above the average during the spring seasons. Wind speed declined. The standardized seasonal rainfall shows an autumn trend that approximates the annual trend with amplitude of five years, while rainfall during the winter declines and inclines above the long-term average during spring. It could be supposed that the situation in Alexandria should be similar for the coastal Omayed BR, but the fact that OBR is within the desert, positions it under the added albedo effect. OBR has as much as 5 times elevation in average temperature (2-3° C) in the period of study as had Alexandria (0.5° C), and even more than Aswan (2° C).

Soil trends showed largest variation in sodium, sulfate and chloride contents (salinity), which increased rapidly late in the 1990s, but to a much less extent, for both calcium and bicarbonate contents. These trends correspond to a remarkable change in the soil texture during the same period, incorporating larger components of the very fine sand fraction. All habitats exhibit increases in soil contents, especially calcium and bicarbonates, while the inland plateau is experiencing a sharp change in its soil texture associated with the increase of sulfate content. However, this trend was lately reversed with declining sodium and sulfate and increasing calcium and bicarbonate contents, associated with the increase in the coarse and fine fractions of the sand. Sodium, sulfate and chloride soil concentrations increased rapidly in the late 1990s, together with increases in the very fine sand fraction, which reflects the active erosion and deposition processes associated with recent more intensive human interference.

For plants, there is a general process of recharging plant species diversity in the late 1990s following a sizeable decline. The change in the diversity of perennial species is allied to changes in rainfall, temperature, wind speed, salinity, bicarbonate, calcium, and sulfates. Air temperature and soil sulfates are especially the most determinant driving factors. Furthermore, a shift of the rainfall above the long-term average from winter to spring shows that the trends of change have an impact on plant diversity. It is concluded that the diversity of biotopes in the area (spatial heterogeneity in habitats), is the influential basis for plant diversity and is greatly affected by the human impact.

Abdel-Razik (2008) concludes that trends in the change of species richness in perennial plants at both the spatial (habitats) and the temporal scales demonstrate two general findings: (1) inland ridges support the highest plant diversity, and (2) except for the inland plateau, where the trend of plant diversity is declining, there is a process of rapid recharge of species diversity (starting in 1999), after a sizable decline along the preceding time period (starting in 1990). The source data reveal that the change in density of the various plant species is unresponsive among habitats (having similar change behaviour), while temporal change in all habitats is generally imposed by the driving factors in force (*e.g.* climate). Climatic change and the associated environmental degradation of soil resources seem to be cyclic (recurring) phenomena, which impart specific feedback effects on biodiversity in the region.

2. DISCUSSION

Climate change is expected principally from an increase in carbon dioxide content in the atmosphere. There are many studies in Europe and USA that look into the effect of an increase of CO_2 in the soil atmosphere on soil fauna (*e.g*. Coûteaux and Bolger 2000, Blankinship *et al*. 2011). However, in the case of the alkaline and calcareous OBR soils, this aspect of climate change is not expected to have any appreciable effect on either soil or soil fauna.

At the smaller and the local scale of this coastal land, the same rules as elsewhere will apply, but at a much more rapid pace, due to the proximity and the small differences in temperature that will prevail. For example, pests that are common but insignificant at a distance of 50 or 100 kms from the coast (the "accentuated xero-Mediterranean" climate class), are expected to rapidly appear in the new plantations at just a few kms from the shore (the "attenuated xero-Mediterranean" climate class), without much obstacles, except perhaps those related to soil characteristics, such as higher grain size).

Higher biodiversity in an ecosystem increases its functionality. Every species has its own place (or niche) and apparently, nothing is really redundant. In consequence, the existence of a balance between functional groups is to be expected. This will appear in natural ecosystems (*i.e*., with least human interventions), as shown at the Omayed and Gharbaniat sites in the western coastal Mediterranean zone. With increasing human interferences through agricultural practices and more intensive land use, there is a reduction in diversity and an imbalance of functional groups, due to increase of species of one functional group (herbivores), engendered by the higher density of the cultivated live plants, over those of another (the detritivores), suffering from less litter fall (Ghabbour 1984). Herbivores increased from 1-4% in natural and semi-natural vegetation, to 12-15% in agro-ecosystems and within the enclosure. In agro-ecosystems, the abundance of living plant material attracts small herbivores, whose presence leads to an imbalance of functional faunal groups. This will lead to less functionality and it is here that redundancy may be provoked, due to the enlargement of available niches (Shakir 1989). However, we must distinguish between ecosystems in transition and those that have reached stability (a climax or a pre-climax). We must also note that desert ecosystems never reach a true climax because of aridity. They are in fact "stunted" ecosystems whose development into mature ecosystems is prevented, or inhibited, by aridity and high temperature conditions. With the introduction of irrigation water, this stunting is released and the ecosystem takes a start on a new development path. When this transitional phase is over, redundancy may disappear as species gradually adjust themselves into an equilibrium, and those that are redundant may disappear with time, due to a settling down of competitiveness.

On the other hand, the degree of climatic variations such as rainfall variability and of temperature and relative humidity, can affect the distribution of soil fauna diversity, and with it the balance of functional groups. For example, in the southern region of Egypt, with hyper-aridity conditions, diversity is lowest (H_a = 0.19), with a percentage of herbivores as low as 3% (Hanna *et al*. unpublished).

Diversity of soil fauna can be different at the micro-ecosystem level rather than the regional one. Regional biodiversity showed that the North West (NW) region of Egypt has more diversity than the South East region (SE) region. This is obviously due to the ecological factors of rainfall (180 mm/yr in the NW against only 0.07 mm/yr in the SE). Different soil types and different vegetation cover are also factors that have their influence, but apparently less than climate.

They act within the limits at which soil faunal assemblages will be allowed to exist, under the prevailing climatic regime (Hanna *et al*. in press).

The degree of intensity of agricultural practices has similar impacts on the diversity of soil fauna populations and their functional groups whether under favorable or unfavorable climatic regimes. Under such conditions, it is likely that a small number of key species have considerable effects on ecosystem functions. The crucial question is whether ecosystems that are more diverse are more resistant or more resilient when environmental conditions change. Concern about decreasing soil organism biodiversity as the result of human impact pressures has been justified with the good argument that high diversity guarantees a source of new species performing functions as human needs or environmental conditions. The diversity of organisms involved in nutrient cycling (the detritivores), may be substantially reduced under harsh climates. Management and development of ecosystems towards sustainability such as in agricultural ecosystems, will depend on our understanding of the linkages between key species and functionality groups and their biological and geographical distribution, as well as their functionality in transitional ecosystems.

The degree of effect of land-use on soil fauna changes has impacted on the diversity and also clearly can provide us with the prediction and monitoring environmental transformation, early warning for pest species, identifying the constrains in decomposition of organic matter and nutrient release and recycling. Studies of the soil fauna in Egypt conducted by many scientists, revealed the importance of soil fauna functional groups in enhancement the agriculture in the desert ecosystem and in other desert areas near the river Nile basin.

Analyses to interpret the data and to extract the most important information indicates that the regional diversity of soil fauna in Egypt could describe habitats and ecosystem health, maturity, and productivity. Further, these methods may be of importance in measuring the intensity of human impact on biological systems and land-use pressures. Finally, this will allow decision makers to understand and develop rational planning theories and techniques, for better and more sustainable land use of both natural and manipulated ecosystems, especially under the impact of climate change.

It is very important to understand that diversity of soil fauna can be different at the micro-ecosystem level as well as at the regional level. The regional biodiversity study showed that the northwestern region is more diverse than the southeastern region. This is most probably (rather certainly), due to the ecological factors such as the level of rainfall and other climatic factors (*i.e*. higher rainfall in the northwestern region [180 mm / year] rather than in the southeastern region [0.07 mm/year], soil texture and vegetation types). For example, some groups, such as the carnivorous Carabidae, disappear entirely from desert regions in the southeast of the country. In some hyper-arid sites, the predator/prey ratio reaches unity, when the expected ratio should be 1:10.

New species invade deserts when irrigation water is brought to desert lands for reclamation. Soil texture and organic matter content also change. Within a certain number of years, the reclaimed desert land in the Mediterranean coast became so similar to the "old" Delta lands, that the process may be called "Deltaisation". The process may take from five up to 20 years, depending on intensity of land use. It is not a surprise then that agricultural pests, such as the mole-cricket and some Lepidoptera, are attracted to these "new" lands.

Analysis of soil fauna functional groups in different regions of Egypt (Hanna *et al.* in press), showed that in general, herbivores are dominant in the newly reclaimed desert areas. Herbivores varied between 2% and 14% of the taxa in the agricultural areas. The detritivores represented approximately between 70% and 90% in agricultural areas. On the other hand, carnivores varied between 1% and 35% of the taxa in the studied regions in Egypt. Furthermore, there are variations in functionality groups of soil fauna in the other types of land-use. These results show that intensity of two of the three soil fauna functional groups (the herbivorous and the carnivorous) is clearly higher in northern Egypt than in the southern part, but that of the detritivores group is high in both northern and southern Egypt, probably being less affected by higher temperatures and lower relative humidity. However, the diversity remains higher in the northern part. The high intensity of the detritivores group in the southern part therefore, has no or little effect on total diversity of soil fauna populations. This supposedly higher tolerance to higher temperatures and to lower relative humidity may not be due to special adaptations in all or most detritivorous species, but could be rather due to their lesser need of moving outside the soil and litter layers.

3. CONCLUSIONS

Based on the above data and arguments, we expect with high certainty that the fauna of the littoral sand dunes living under the wetter regime of the "attenuated xero-Mediterranean" class of 180-200 mm rainfall/year, will mostly disappear. They may be replaced by the fauna characteristic of the next zone of the "accentuated" class, now existing at the non-saline depression of the OBR. These may in turn be replaced by the fauna of what we suggest to be called the "hyper accentuated" class. These in turn will be replaced by the fauna of the Mariut Frontal Plain. Both the vegetation and the fauna are expected to be similar to the vegetation and fauna now existing on the coast of the Gulf of Syrte in Libya (Nègre 1974, for the vegetation, Le Houérou 1986 and Ayyad and Ghabbour 1994, for ecosystem description). At Syrte, which is where the Sahara actually very closely meets the Mediterranean coast, although average rainfall is 172 mm/year.

Nevertheless, we have to remember that in the coastal Mediterranean deserts of Egypt, there is a "permanent" wet layer at a 50-70 cm depth, and that soil temperatures at this depth are almost constant. As a general rule, soil fauna because they live in such a secluded environment, are a "conservative" community, meaning that they may persist in living within the soil medium for several years, decades, or probably centuries, even after climate has (moderately) changed and even after the above-ground vegetation has changed (Ghabbour 1991). Because of this, although northward shifts of soil fauna populations are to be expected, they are, however, expected to take place at a pace much slower than that of the expected vegetation shifts, or the shifts in above-ground fauna. Moreover, there will also be other important factors governing this northward shift of soil fauna populations, such as soil texture, penetrability, salinity, litter quality, etc. We know that at least one species will be better off in the littoral sand dunes. This is the "sand roach" *Heterogamia syriaca*, which has the ability to absorb water vapour from unsaturated air, and is adapted to burrowing to considerable depths in friable sand (Vannier and Ghabbour 1983). Isopoda (woodlice) are also expected to benefit from this climate change. Both taxa are highly efficient detritivores.

On another note, an unpublished study, Ghabbour and Vannier (1992), examined the risks posed by the migration of new pests adapted to high temperatures in North Africa, to cooler regions in southern Europe that will become gradually warmer, according to expectation. Knowing that these species are adapted to the warm climate of the southern Mediterranean countries, the limiting factor for their establishment in southern Europe will be their ability to withstand the cool winter temperatures. It is their ability to withstand and to adapt and to survive the low winter temperatures, not to the higher summer temperatures, that will determine their invasive capacities there. The study has shown that we can distinguish three groups of potential insect pest species regarding this risk:

1 – Species that are by chance pre-adapted to the relatively cooler climate of southern Europe. These will be the first to appear as pests there.
2 – Species that will take some time to be acclimatized to cooler conditions. They will constitute the second wave of pests.
3 – Species that cannot acclimatize to cooler conditions. These are not likely to pose a threat of pest invasions.

Therefore, it is highly recommended to carry out screening experiments on the heat tolerance and acclimatization capacities of Egyptian pest species, even the least conspicuous of them, in order to predict which will be the more successful in invading agro-ecosystems of the Egyptian Mediterranean coastal lands, to give early warnings about them and to prepare contingency plans for their control.

4. FUTURE PROSPECTS

Egypt has only two Biosphere Reserves so far, one (the OBR), in the north representing the xero-Mediterranean climate regime, and the other (Wadi Allaqi BR) in the southeast, representing the hot dry tropical regime. They are both active and doing significant services at both community and scientific research levels. Nomination of two others BRs is under preparation: Wadi Gemal on the Red coast and the other at St. Catherine (montane). The risks of climate change, involving prospects of both high temperatures and lower rainfall, impose a responsibility on the Egyptian scientific community in universities, government administrations, and NGOs, to tackle these prospects seriously. We suggest:

- Introducing studies of climate change into school and university curricula,
- Establishing a mitigation and an adaptation plan to be applied in BRs, which are designated as “Laboratories for Sustainable Development”,
- Experimenting the potential risks of pests and diseases due to the expected climate change.
- Building capacity to implement these plans,
- Raising awareness among the population at all levels about the local negative impacts of climate change at the national level,
- Establishing cooperation agreements with international organizations for assistance in implementing the Egyptian Action Plan,

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