ASSESSING SOIL DEGRADATION BY LANDUSE-COVER CHANGE IN COASTAL LEBANON

Talal Darwish, Ghaleb Faour and Mohamad Khawlie
National Council for Scientific Research, National Center for Remote Sensing
P.O. Box 11-8281, Beirut, Lebanon
tdarwich@cnrs.edu.lb

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ABSTRACT

Change in landuse is rapid in Lebanon straining its narrow coastal strip. Chaotic urban expansion in the last forty years resulted in consumption of prime soils and degradation of most productive lands. This study aims to show such expansion in Tripoli, the country's second largest city of 61.5 km^2, and to evaluate the impact of landuse change on soil sealing and degradation by integrating remote sensing and GIS techniques. It will gear to more optimal landuse planning based on assessing the result of chaotic landuse change. Social and economic soil functions were involved and soil capability and land suitability compared. Quantifying land cover/use change in the pilot area was arrived at through analysis of multitemporal sources using airborne-based detailed topographic maps (1:20000 scale) from 1962 and satellite imagery IRS-1C, 5-meter resolution from 2000. The topographic maps contain detailed information on land use, like agriculture and type of forest with corresponding borderlines, urban areas with real geometric shapes and other info. This allowed identifying and grouping the data and comparison with that gathered from the high-resolution satellite images.

The resultant change showed an increase of 208% of urban area with a decrease of 35% in agricultural lands. Secondary forest and shrubs replaced the orchards on the abandoned lands. Concerning land capability, 32% of class 1 (prime land) and 26% of class 2 land, i.e. 971 ha, were converted into urban area. Obviously, urban expansion occurred at the expense of rare fertile soils with citrus orchards of the coastal plain like Fluvisols, Luvisols and Cambisols belonging to the most productive agricultural land.

Major structural changes in landuse between 1962 and 2000 occurred in the agricultural and urban sectors. Analyzing current landuse pattern, in view of requirements for sustainability, shows that about 10% of prime lands were properly used. Overall, only 22.6% of land is fairly used, while 46% is poorly used and 31.4% is misused. Providing a proper management of water resources, the geographically isolated southeast area with productive lands currently allocated for low-income olive monoculture could be used for more balanced agricultural production. Water harvesting and management will also provide adequate irrigation water for perurban agriculture.

Keywords: urban sprawl, land degradation, landuse planning, soil protection, land capability, land suitability

INTRODUCTION

Rapid changes in landuse were recorded worldwide during the last quarter of the twentieth century, with urbanization extending to rural areas (Anys *et al.*, 1999). A similar trend is witnessed in the eastern Mediterranean along the coastal Lebanese strip (Huybrechts, 1997; Awad *et al*., 1999). A dynamic growth typifies the long history of human settlement in the Mediterranean with lands being subject to increasing stresses. High quality soils are rare and at risk of degradation and loss through urbanization (OECD, 1997). Human impacts on land resources in this area have been intense and continuous, notably affecting productive soil (Darwish *et al*., 1999). The increasing population with expansion of construction areas and rapid urban growth has been a principal cause of land degradation in the Mediterranean countries (Eswaran and Reich, 1999).

Coastal Lebanon is a narrow strip with limited land resources. Endurable growth in the area could be based on adapted international criteria and landuse ratings. A framework was proposed for zoning and planning, as necessary tool to provide optimal ways for progress, like sustainable land development model (Yeh and Li, 1998). The global assessment of soil degradation (GLASSOD) provided a structured recording of severity and nature of land degradation (Nachtergaele, 2000).

A resulting set of vulnerability maps characterized stable lands as lands with minimal human intervention due to low population density or regions where soil protection programs have been successfully implemented. Mapping soil and terrain vulnerability in Europe (SOVEUR) was studied through developing a soil and terrain digital database (Batjes, 2000). Land management with regard to suitability assessment, productivity and use of resources could also be approached through morpho-pedological studies using GIS (Loukili *et al*., 2000).

To study these aspects in Lebanon, early attempts focused on the use of aerial photos to analyze the landscape pattern developed over specific substratum (Verheye, 1988). More recent studies used remotely sensed data to assess land resources for soil studies and mapping (Darwish, 1999), monitor soil vulnerability to water erosion (Faour *et al*., 1999; Boukheir *et al*., 2001), desertification (Khawlie and Faour, 2003) and pollutants movement in karstic rugged mountainous areas (Khawlie *et al*., 2002). However, the country still lacks a comprehensive management plan allocating different lands their use requirement based on respective capability and suitability.

Tripoli, the second largest city in Lebanon (Figure 1), is an important place for business, commerce, and social interests. Historically, the city used to represent an important trade center along the Silk Road between Asia and Europe. It is famous for its historical monuments and archeological sites, harbor and its past orchards and gardens. Being in the vicinity of land with large agricultural production, the city attracted people from other areas of Lebanon and from neighboring countries. However, the last few decades, the area has been subject to radical landuse changes reflecting the structure of economic occupation and urban growth. Based on soil criteria for engineering purposes (FAO, 1973), urban construction was oriented towards lands showing good rating for buildings.

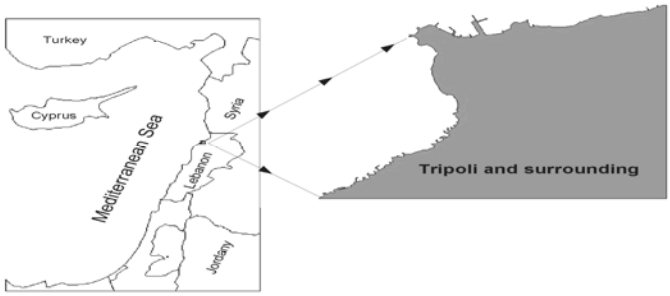

Figure 1. Index map showing Tripoli-Lebanon along the Mediterranean.

With the priority given to the economic growth through tourism and service, the absence of integrated planning yielded conflicting land use, soil sealing and environmental deterioration. The problem of sustainable landuse lies in the competition between the ecological, technical and socio-economic functions of soil (Blum, 2000). Accordingly, this paper integrates the remote sensing and GIS techniques to quantify the change in land cover/use and its pressure on soil resources. It focuses on urban sprawl at the expense of agricultural lands belonging to different capability classes for the purpose of better understanding of sustainable landuse.

DATA AND METHODS

The area of study, which is around 61.5 km^2, encompasses the administrative borders of Caza Tripoli (Caza is a district boundary) and surrounding suburbs. The area extends along the eastern Mediterranean grading up in elevation between sea level and 300 m. The coastal western part consists of a Quaternary level plain with alluvial clay with indurated sandy sediments. To the east the area becomes hilly with sloping lands consisting of hard limestone, conglomerate and marls separated at the middle by the drainage of the River Abou Ali filled with deep sediments and conglomerates. Tripoli City developed rapidly as reflected through population increase from 136000 in 1984 to 212000 in mid nineties. With the surrounding suburbs that number comes closer to 350000 (Ministry of Social Affairs, 1996).

Due to mild Mediterranean climate and the availability of water for irrigation a continuous crop production is possible. Major crops include citrus, olives, and horticulture cultivated mainly on prime lands. To study changes in land use and urban expansion topographic maps from 1962 at 1:20000 scale based on aerial photos were used as baseline data. They distinguish urban stretch with real objects contours and geometric shapes, fruit trees like citrus and olive orchards, forest, shrub, grassland, field plantation, terraces, rocks and bare lands with corresponding colors and lines boundaries. After exact delineation, regions enclosed by these lines were identified, coded and digitized. Then the same area was classified through visual interpretation of satellite image from landsat TM (30m), merged with IRS-1C, 5-meter resolution from 2000. Both satellite images were orthorectified using digital elevation model, extracted from topographic maps scale 1:20000 with a contour line of 10m, and available sensor parameters. This processing was done using the orthobase module of Erdas Imagine software version 8.4.

The legend of interpretation was elaborated from the European Corrine nomenclature adapted to Lebanese conditions. The differences in various land uses over the forty-year period were aggregated to allow comparison, measured and quantified. It shows the following categories of landuse: urban land (residential, industrial, commercial and tourist facilities), olive orchards, citrus, field crops, shrubs, grassland, forest, and Abou Ali River. Bare lands and rocky areas were grouped into non-productive lands. The satellite image allowed distinguishing quarries, land fills, dumped sites and plastic (green) houses.

To evaluate the soil cover, data was manipulated through GIS to construct maps of land capability classification. Land capability is a characterization of land through classes based on geomorphology, physical and chemical properties of the soil and its capacity to produce crops. The less the soil needs costly treatment to produce the same product, the better the land capability class is (Soil Survey Manual, 1993). Due to the restricted soil information in the country to an old soil map at 1:200000 scale (Geze, 1956), work was followed to produce a new pedological map at larger scale to provide more accurate information about the soil cover.

Soil database was accomplished in 2000 according to the adapted georeferenced agroecological Soil and Terrain Database, the SOTER (Oldeman, 1994). The SOTER approach combines terrain units (TU), *i.e.* elements constituting major landform and lithology, terrain components (TC), and soil components (SC) to produce the SOTER units. The database has been supported by new images, extensive recent fieldwork and soil sampling.

Soil profiles were described according to the FAO methodology (FAO, 1990a). From each soil type, horizons were described and sampled for further analyses for the main physical and chemical properties according to the methods adapted for the MENA region (Ryan *et al*., 1996). Limitations for a gricultural use are those indicated in the Instructions Guide for the Elaboration of the Soil Geographical Database of Euro-Mediterranean Countries (Lambert *et al*., 2000). Land capability classification was based on such criteria like soil type, soil physico-chemical properties, regional landform, drainage and erosion hazards. This is in accordance with the thresholds and trends referred to from international and European standards (Soil Survey Manual, 1993; European Soil Bureau, 1998).

RESULTS AND DISCUSSION

Land cover/use

The comparative analysis of land cover/use of the 1960's and 2000 reveals eight main categories (Figure 2a and 2b). Their change detection shows the following: 1. Urban area increased about 208%, 2. Olive plots decreased about 31%, 3. As a result of deteriorating citrus production, which declined by 37%, and the appearance of compensating agricultural activity on the hills, the total area of other agricultural land decreased by 4% only, 4. The forest cover was increased by 322%, 6. The area of shrubs increased by 100% and 7. The non-productive lands were reduced by 86% (Table 1).

In the early sixties the region was mainly one with fruit tree production of small parcel areas and limited water resources. In 2000, new patterns in land use/cover were detected, consisting of field crops, quarries, bare lands, tourist facilities, industrial and commercial complexes, salt production areas, landfill and dump sites. This indicates a shift in the farmers' occupation from citrus production to other agricultural and technical activities.

TABLE 1
Observation of Land Cover/Landuse Changes Between 1962 and 2000 in Tripoli

Classes		Surface (ha)		Observed change		% From total		Structural changes
		1962	2000	(ha)	%	1962	2000	%
Forest		32	137	+105	+323	0.5	2.2	+1.7
Olive		3055	2121	-934	-31	50.5	34.5	-16.0
Other agricultural land	Citrus	928	581	-347	-37	15.3	9.4	-6.0
	Field crops	-	310	+310	--	--	5.1	--
	Green house	-	1	+1	--	--	0.02	--
Shrubs		133	246	+113	+100	2.2	4.0	+1.8
Grassland		333	318	-15	-4	5.5	5.2	-0.3
River borders		81	24	-57	-71	1.4	0.4	-1.0
Non productive land		769	110	-659	-86	12.7	1.8	-10.9
Urban land		722	2223	+1501	+208	11.9	36	+24.2
Total area		6053	6151	+98*	1.6	--	--	--

* Represents the new artificial coastal line west of the city.

Analyzing the structural landuse pattern from Table 1 reveals a low initial proportion of forest to urban area (4.49%) in 1962 and to total area (0.53%). This further substantially increased in 2000 to become 6.16% and 2.25%, respectively. Local improvement remains below the remotely acquired data on the ratio of forest to total country area in the late eighties, which reached 6% (FAO, 1990b, Masri *et al*., 2002). Obviously, the comparison of forest area from multitemporal platforms is relative and affected by the mapping scale and forest definition.

Citrus trees and olive orchards that occupied 65% from total in the 1960's were reduced to 44% from total in 2000. Such change indicates a remarkable structural change over 39 years in the activity of the population. Citrus production requires continuous farmer involvement and inputs whereas olive tree is relatively less demanding and more resistant to drought. The focal socio-economic reason could be the escalating competition and loss of regional and European markets. This reflects less dependence on agriculture as a main supply of income.

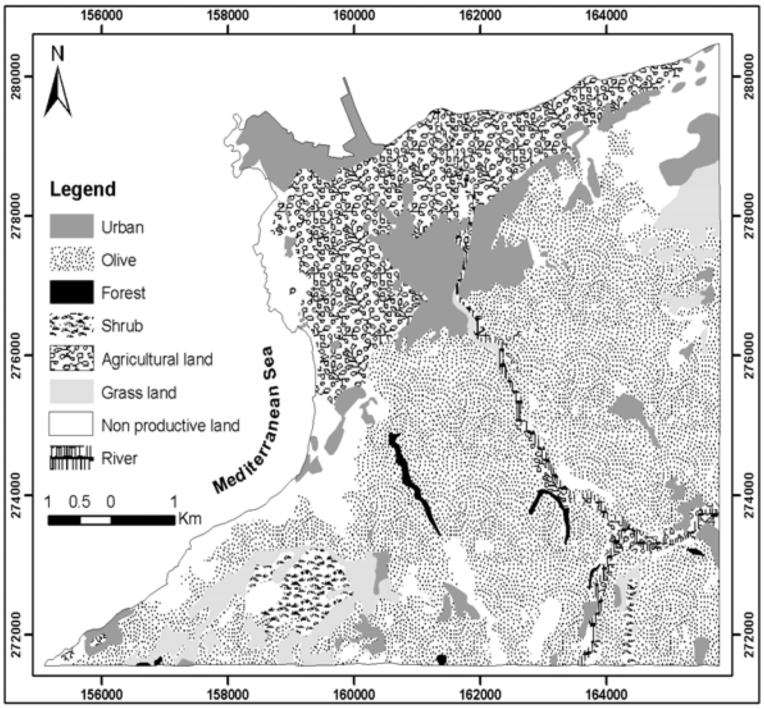

Figure 2a. Land cover/use in 1962 detected from the topographic map.

Change in landuse was accompanied by reliance on commercial activity and real estate business despite hesitant ''perurban'' vegetable and greenhouse production. The driving force behind that is the market conditions, water shortage for irrigation and low quality of available water.

Moreover, an artificial coastal line of 96 ha was built south of the city representing a large tourist site. Tourism and industry created conflict in water sharing. Urban growth at the plain caused a disproportion between the land value and net return from agriculture. The relatively high exploitation rate within the administrative borders of the city multiplied the price of land, therefore, magnified the pressure. Plots of citrus and olive orchards, traditionally occupying prime soils were abandoned, and cleared land was allocated for construction resulting in a substantial loss in soil resources. The absence of agricultural policy and low profit from agriculture did not encourage farmers to reinvest into this sector by rehabilitating the low price lands of the hills, east of the city. Instead they become part of the service economy, which requires regional and local political stability.

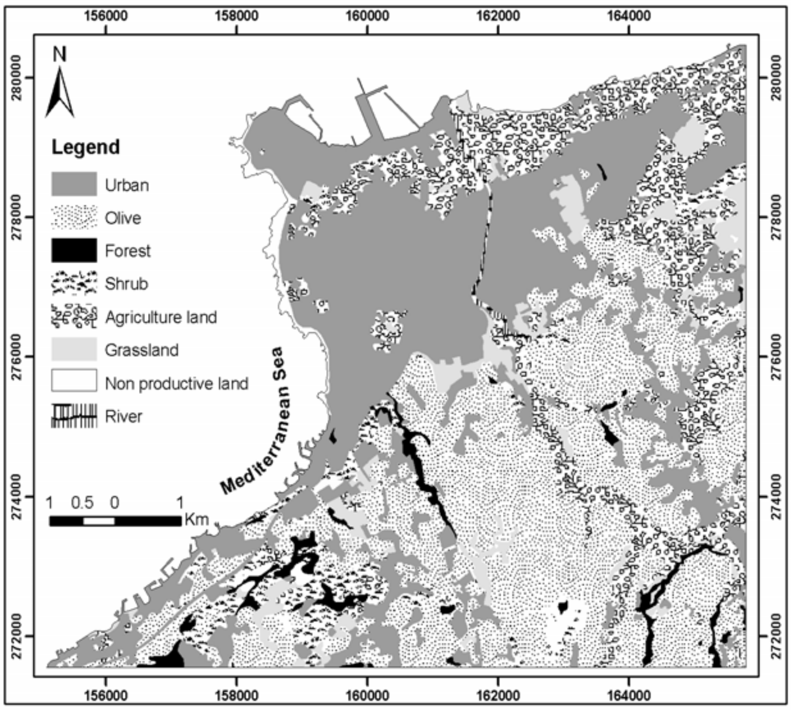

Figure 2b. Aggregated land cover/use in 2000 detected from the satellite image.

Land Capability classification

The main objective of the classification is to divide the study area into zones or units with similar types and degrees of agricultural limitations. Hence, each land capability class represents a group of soil units of sufficiently similar conditions as to assign their agricultural productivity level. Different weights are attributed to the factors of land productivity depending on their importance to determine the capability of the land. The data augment the database's usefulness and facilitate its application for major classes of landuse, their environmental functions, and sensitivity to degrading influxes and land capability classification (Montanarella and Nègre, 2001).

The implementation of the methodology revealed five classes, out of eight possible (Soil Survey manual, 1993), four among which relate to arable lands and one to non-arable lands. The non-arable lands are rock, extremely shallow soils spread over steep lands. They are very locally represented in the area of study as the city spread from the foothills towards the level coastal plain. The arable lands are arranged from class I Fluvisols, Cambisols and

Luvisols, characterized by a high productivity, to class II Arenosols representing some limitations like the excessive infiltration rate.

The third class was allocated to Vertisols and calcareous soil units requiring investments to improve physical properties and careful management of water scheduling to prevent soil cracking and plant chlorosis. The IV class represents Leptosols and Calcisols, i.e. marginal sloping land that can be safely used for grazing, forestry, leisure and wildlife and require important rehabilitation or conservation measures for agricultural production.

City planning and actual landuse

The old master plan of 1971 for the development of the city projected for the subsequent 25 years an urban expansion of 339 ha, 90% of which falls on best productive lands (Table 2). The intersection of land use and soil capability maps showed a total actual loss of 1430.5 ha of agricultural land between the 1960's and 2000. Among these, 971.4 ha of rare productive soils were converted into urban areas. This represents a relative mean loss of 32.3% and 26.2% of classes 1 and 2 soils, respectively. The magnitude of soil loss in the context of agricultural potential, social and ecological functions threatens the biodiversity and sustainability for the coming generations.

Soil and green cover loss to urban expansion has been also noticed in other countries of MENA region. Land use planning contributed to alleviate the problem in Morocco for example, where urban expansion principally occurred at the detriment of non-irrigated agricultural land (Anys *et al*., 1999). The residential encroachment on the remaining green cover in and around Tripoli city is associated with a more dense construction inside the city. Moreover, the exploitation of the coast through the building of private sea resorts hinders public access and destroys the natural balance of the seashore.

TABLE 2
Loss of Soil Resources in Tripoli

Land Capability		Planned* urban landuse ha				Actual urban expansion	Relative loss of land
Classes	Area ha	Historical	Tourism	Industry	Residential	ha	%
1	989	91	32	47	231	319	32
2	2493	1	-	51	73	652	26
3	2258	12	-	11	-	400	18
4	233	1	-	9	35	52	2
5	81	-	-	-	-	6	7
Total area ha	6054	593				1429	--

*Law N0. 1915 of 14/09/1971.

The analysis and classification of the recent occupation of lands contrasted to proper landuse requirements demonstrated that 22.6% of lands are reasonably used, 46% are defectively used and 31.4 % are misused (Table 3). This differentiation in quality of landuse is assessed by matching land capability and best-practice landuse requirements (Soil Survey Manual, 1993). Referring to their capability classes, the lands allocated for fruit trees and field crops are fairly used. In the context of soil scarcity, high quality fruit tree production could serve as a feasible alternative to weakly competing field crop production. However, concentrating rainfed olive production on prime lands is a poor use of limited resource, as landuse could be intensified to secure higher income, unless high quality olive oil is classified, labeled and exported.

Securing additional source of water for agriculture will conflict with the domestic needs. This raises the question on better water management including wastewater treatment and reuse, notably that derived from domestic wastewater and olive oil production. A large isolated depression with prime lands currently used for olive production requires intensive labor work and is characterized by a low input and high polluting potential. Drainage water from olive extraction carries polluting organic substances affecting the quality of the surface and groundwater as well as the downstream lands. Adapted treatment and water harvesting by building small dumps and reservoirs upstream would provide the ground for diversified land use and possibly organic farming.

On the other hand, the abandoned citrus orchards and conversion of lands having capability classes 1 and 2 into urban areas could be regarded as non-sustainable use of limited soil resources (Figure 3). City planners usually consider the ease of infrastructure development and maintenance to expand urbanized areas. However, from the agricultural standpoint, 87% (1237 ha) of prime lands are misused when deliberately or chaotically put under construction. From the environmental and sustainability points of view, only 18% of these lands could be considered as fairly used when construction consumed lower capability classes. Chaotic urban distribution hindered the flow of rainwater in the natural drainage canals, which magnified flooding risk and soil erosion.

On the other hand, the increase of the proportion of fairly used lands in the lower capability classes creates an impression of a proper planning. Instead, this appears to be a warning indicator demonstrating mismanagement of land resources in a country with extremely skimpy soil resources. There is, however, a possibility to strengthen the basis for sustainable agriculture and ecotourism providing appropriate land conservation management. Without proper zoning and planning of the remaining unplanned 70% of the Lebanese territory, based on land resources appraisal and constraints, such chance remains pathetic. Because soil is one of the most limiting factors of production in Lebanon, soil conservation should be regarded in close connection with the sustainable agriculture and environmental protection (Darwish, 2003).

Monitoring changes in landuse by integrating the data acquired from detailed topographic maps based on aerial photos, remote sensing and GIS proved to be efficient to assess the environmental impact of land degradation. Land cover change detection in eastern Mediterranean using different space based platforms revealed to be a workable tool to support decision-making (Gitas *et al.,* 2003). Intersectorial and integrated information was obtained

TABLE 3
Structure and Evaluation of Recent Landuse in the Classified Part of Tripoli Based on Land Allocation*

Land capability	Urban		Fruit trees		Bare land		Grass land		Field crop		Olive		Forest	
	Area, ha	Evaluation	Area, ha	Evaluation	Area, ha	Evaluation	Area, ha	Evaluation	Area, ha	Evaluation	Area, ha	Evaluation	Area, ha	Evaluation
1	773	M	239	F	28	M	340	M	6	F	811	P	12	P
2	464	M	7	F	1	M	59	P	2	F	0	-	0	-
3	290	F	14	F	53	P	193	P	1	P	130	F	7	F
4	57	F	16	F	33	P	82	P	0	0	18	F	1	F

* F- fairly used; P- poorly used; M- misused.

obtained through remote sensing to derive indicators of country vulnerability to desertification (Khawlie and Faour, 2003). These techniques provided a powerful data for spatially explicit landscape evaluation using suitable models for assessing specific landscape functions (Backhaus *et al*., 2002). Comparing landcover/use change on a multitemporal basis between 1962 and 2000 allowed finding out the impact of urban stretching on per-urban agriculture both in time and space. A lack of implementation of the Lebanese ‘’Code of Urbanism’’ is observed which stated that any urban plan must conclude ‘’ protected lands for agricultural use’’. The enforcement of such law revealed to be tricky and difficult because of the boom in urban expansion and the will of the landlords to avoid a formal classification of their lands for rural and agricultural purposes (Mallat, 2003).

Despite the promulgation of earlier law (9/11/1951), which granted the Ministry of Agriculture with the authority of implementing a soil protection and reforestation policy and to finance the recuperation of the pastures with the payment of the indemnity, land protection in Lebanon still weak. The absence of policy and sustainability indicators was in charge for the priority given to economic growth and consumption (Abolina and Zilans, 2002).

The spreading out of forest area in the suburbs of Tripoli was may be due to the abandonment of agricultural lands, where natural vegetation gradually recovered. However, the relativity of such speculation might be linked to the difference in forest definition used in different mapping procedure. Similar process was detected in other areas, despite the demographic pressure, where secondary forest sheltered the old terraces and abandoned rangelands (Masri *et al*., 2002; Vanacker *et al*., 2003). The expansion of grasslands-croplands and reforestation with coniferous species, under humid climate, were responsible for fragmen-

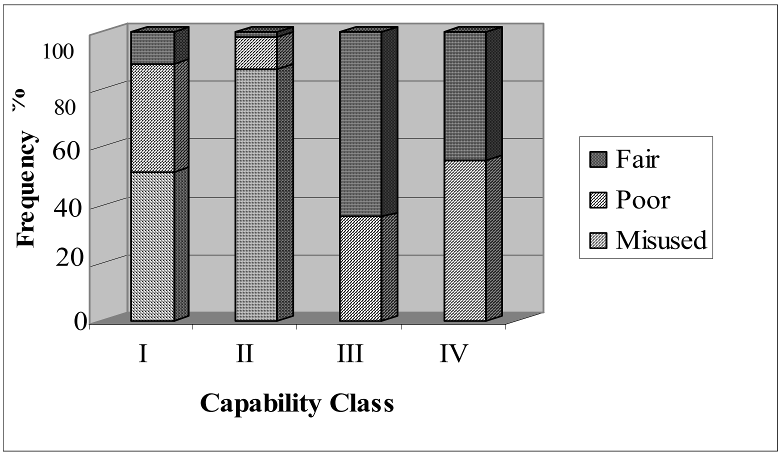

Figure 3. Assessment of current uses in view of land capability and suitability.

tation of landscape structure (Petit and Lambin, 2002). Positive and negative changes in land cover have also been observed between 1987 and 1998 in two sites from Lebanon subject to quarrying and agricultural expansion (Jomaa and Bou Kheir, 2003). Similar opposite trends were also detected in Syria, Turkey and Egypt between 1992 and 1999 and explained by new irrigation facilities or soil baring by inter-annual climate variability (Gitas *et al.,* 2003).

With originally scattered, "patchy" land ownership and less humid climate, the observed land resilience witnesses ability of the Lebanese nature for fast recovery if management and protection are put into action. An example of this could be the spontaneous regeneration dynamic in a thermo-Mediterranean biozone of Lebanon, where annual grass dominated on very perturbed sites, while on less degraded and non-degraded areas within the quarry shrubs and woody perennials dominated (Khater *et al.,* 2003). Experience of developed countries shows that an integrated planning and coordination among policy makers, geomorphologists, soil scientists and RS specialists yielded best results for natural resources, land management and protection (Slaymaker, 2001).

Even under arid conditions, four years of protection in the Kuweit desert allowed the dwarf shrub to recover with a cover value compared to the 20-years protected site accompanied, however, by a reduction in the biota richness (Brown and Al-Mazrooei, 2003). The effect of the field crop area and woodland habitats increase in north Lebanon could be associated with a decline in the quality of some terrestrial biotopes indicated by the loss of species diversity from agricultural habitats (Haines-Young *et al*., 2003). This could be prevented if proper information is available, and if an integrated evaluation system that considers social as well as economic performance and the overall effect on environment is considered (Mulders, 2001; Prizzia, 2002). This will help avoiding global scale collapse due to environmental catastrophes (Glasby, 2002). Sealing the non-renewable soil resources threatens the agro biodiversity with resulting landscape change and damage of ecosystems with unpredicted socio-economic consequences. A sustainable development requires relinquishing the least fertile soils for the purpose of industrial and urban enlargement.

CONCLUSION

The fragile Mediterranean coastal strips, including North Lebanon, are facing increasing urban encroachment, which results in deep land cover change. This process is associated with changing population activities as agriculture has lost its importance as a source of income. Spontaneous regeneration of natural vegetation transferred the neglected fields into mixed trees-shrub-grassland. A more objective evaluation of forest cover change can be reached trough unifying the definition of forest in different mapping procedures. In general, the purpose of monitoring landcover/use change was to understand better how to secure proper urban growth and a healthier environment through understanding the dynamics of landuse change in the Tripoli city, notably any loss in its prime productive land.

The approach followed is by the analysis of changes in landuse from the 1960's to 2000. The methodology focused on comparing spatial landuse representation of air-borne topographic maps of the sixties to satellite-imagery constructed layouts of the year 2000. The emerging significance is the fact that such analysis allows linking, and explains urban dynamics especially ill planned urban growth, to the land degradation observed today. Land is classified taking into consideration its agricultural productivity, as it has served the needs of the growing population. Land suitability and soil characteristics are investigated in the field resulting in five different categories, or ''classes'', of land having preferential value. With the conversion of 971 ha of productive soils into construction areas and deterioration of agricultural sector in one site, building the detailed georeferenced soil database and mapping soil degradation on the country level is a first step towards sustainable land use planning.

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