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ASSESSING LAND DEGRADATION IN THE ESCWA REGION:

A METHODOLOGICAL FRAMEWORK

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EXECUTIVE SUMMARY

Land degradation can be understood as a set of multidimensional and multi-scale processes, natural or human-induced, resulting in the decrease and eventual loss of productivity. The physical, chemical and biological dimensions of land degradation are manifest in as many types of degrading processes. The biophysical processes of land degradation have been the attention and focus of natural scientists for many years. Yet, the human, social, economic and cultural dimensions of land degradation have been less studied and are poorly understood. Even less understood are the linkages between the biophysical processes and the socio-economic factors, driving forces and pressures that cause land degradation.

Countries in the ESCWA region consist mainly of fragile dryland ecosystems from which populations derive their livelihoods and existence. The advance of land degradation and the onset of desertification threaten these ecosystems. Therefore, it is imperative to count with reliable estimates of the nature, intensity and extent of human-induced land degradation, while accounting for the driving forces and pressures that cause such states. These estimates should be clear, accurate and unambiguous, and the product of the application of a carefully-designed methodology, relying on fundamental principles of science and holding great practical value.

This document presents a methodological framework for the assessment of land degradation in the ESCWA region, based on indicators of driving forces-pressures-state-impact-response (DPSIR) approach. A similar DPSIR approach has been successfully applied in several case studies within the context of the land degradation assessment in dryland project (LADA) by FAO and UNEP (FAO, 2004). The framework structure is quantitative, multi-scalar, modular and flexible, allowing for the adaptation of methods and procedures to the local circumstances of the assessment.

The results of an empirical test of the framework in Lebanon provides an illustration of the nature of results that can be attained with the use of the indicator-based, DPSIR methodological framework for the ESCWA region.

I. INTRODUCTION

Land is an essential natural resource, which is central to most human activities that sustain life in the planet. The degradation of land therefore acquires a special significance to those whose livelihoods depend on the productivity of land. Land degradation, in essence, threatens the continuity and viability of the means of production, sustenance, security and survival.

Land degradation can be understood as a set of multidimensional processes, natural or human-induced, resulting in the decrease and eventual loss of productivity. The physical, chemical and biological dimensions of land degradation are manifest in as many types of degrading processes. The biophysical processes of land degradation have been the attention and focus of natural scientists for many years. Yet, the human, social, economic and cultural dimensions of land degradation have been less studied and are poorly understood. Even less understood are the linkages between the biophysical processes and the socio-economic factors, driving forces and pressures that cause land degradation.

Desertification (or land degradation in drylands) has been the focus of much political and technical attention in the global arena for nearly 20 years. International agencies have long acknowledged concerns about the nature, intensity and extent of land degradation in drylands, and identified it as a global environmental, economic and social problem in need of large-scale efforts to address it (UNEP, 1977; FAO, 2002). However, efforts to realistically and effectively implement land degradation controls and management measures, with a view to stop desertification on the ground, are fraught with enormous technical, social and policy challenges. The inventory of degraded lands is the primary step to address desertification.

The countries of the ESCWA region hold fragile dryland ecosystems that are the source of livelihood to a large population in the region. The state of land degradation in the region has in part been catalogued, but as in many other areas of the world, attempts to determine the state of land resources have been met with the realization that not enough is known about the nature, severity and extent of land degradation and about its causes and impacts on populations. Efforts to characterize and quantify the type, intensity and extent of land degradation processes at multiple scales, in the global context and in the drylands of the ESCWA region in particular have provided valuable data and information. Yet, many questions remain, particularly related to the linkage between the state of degradation and its root causes (i.e. driving forces and pressures) and impacts on livelihoods. There is an obvious and urgent need to incorporate knowledge gained from past assessments with current assessment techniques that are integrative and holistic enough to determine causative linkages, in order to connect land degradation processes and states to their root causes in order to answer pressing questions that will provide decision and policy makers in the region the information they require to formulate relevant and effective policy.

The design of a methodological framework for the assessment of land degradation in the ESCWA region, that addresses the concerns stated above, and yet provides users with a reliable, flexible, quantitative and reproducible assessment framework of methods and procedures, is the main objective of this report. The methods and procedures in the framework are to be validated through one case study followed by assessment activities to be undertaken by ESCWA countries in their dryland jurisdictions. The land degradation methodological framework proposed here, while considering the tested elements of past and present methodologies, should integrate the biophysical components of land degradation to the social, economic, cultural and policy contexts where degradation occurs so that the identification of causes and responses to degradation as well as its impacts on livelihoods of rural populations can be known.

An overview of the major determinants and effects of land degradation in the ESCWA region will be provided followed by a review of existing approaches, methods and models for assessing land degradation. A methodological framework approach for land degradation assessment in the region is then presented, followed by a case study for Lebanon, where the proposed framework approach was applied.

II. LAND DEGRADATION IN THE ESCWA REGION

This chapter will provide an overview of land degradation issues affecting the ESCWA region. A discussion of the main drivers of land degradation in the region follows, providing a characterisation of the causal factors and identification of the direct and indirect individual and cumulative effects of land degradation in the region.

A. OVERVIEW OF LAND DEGRADATON ISSUES

Land degradation can be understood as a set of multidimensional processes, natural or human-induced, resulting in the decrease and eventual loss of land productivity. The physical, chemical and biological dimensions of land degradation are manifest in many types of degrading processes.

The UNCCD defines land degradation as "...a reduction of resource potential by one or a combination of processes acting on the land, such as:

(i) Soil erosion by wind and/or water;
(ii) Deterioration of the physical, chemical and biological or economic properties of soil; and
(iii) Long-term loss of natural vegetation" (UNEP/GEF, 2002).

A distinction must be made between human-induced and naturally occurring land degradation. Human-induced land degradation is usually a result of a mismatch between the land quality or capability and the intensity of the land use(s) activity occurring on the land. Whereas naturally occurring land degradation occurs with no influence from human activity. The degradation of land becomes a concern when the loss of land productivity directly or indirectly impacts the livelihoods of people in or around the degraded area and no adaptation to the change is easily achievable.

Land degradation is a common problem in dryland areas and can lead to desertification, which refers to "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (UNCED, 1992). Desertification is caused by both natural and social processes, which usually are inextricably linked, each playing varying roles in individual local situation.

Drylands are broadly defined as areas where P/PET <0.65, where P is the annual precipitation and PET is the potential evapo-transpiration (calculated most commonly with the Penman formula), and are often sub-divided by degree of aridity into the following categories:

	P/PET
Hyper-arid	<0.05
Arid	0.05 - 0.20
Semi-arid	0.20 - 0.50
Dry sub-humid	0.50 - 0.65

The combination of low, erratic rainfall and poor vegetation cover frequently coupled with fragile soils, make dryland areas particularly vulnerable to processes of degradation (FAO, 2004). Climatic variations aggravate human dimensions of the degradation problem; recurrent droughts, floods, crop failures and other disasters, lead to increased food insecurity and vulnerability and in extreme cases famines, epidemics, large-scale displacement and deaths in the local populations.

It was estimated in 2002 that some 2.6 billion people were affected by dryland degradation in more than one hundred countries which cover more that 33% of the earth's land surface (FAO, 2002).

Desertification has been the focus of much political and technical attention in the global arena for nearly 20 years. International agencies have long acknowledged concerns about the nature, intensity and extent of land degradation in drylands, and identified it as a global environmental, economic and social problem in need of large-scale efforts to address it (UNEP, 1977; FAO, 2002). The issue of desertification was the central focus at three major international meetings at which it was made a priority issue in the global agenda. Targets were set regarding the need to evaluate the global extent and severity of the problem, monitor changes and reverse the process (UNEP, 1977; UNCED, 1992; UNCCD, 1994).

However, efforts to realistically and effectively implement land degradation controls and management measures, with a view to stop desertification on the ground, are fraught with enormous technical, social and political challenges. The physical processes of land degradation lie in the realm of natural sciences, however the factors encouraging those processes and the reasons for the lack of progress in countering the effects of degradation are an issue primarily of social science (Blaikie, 1987, Stiles, 1995). There appears to be a growing consensus that the social aspects of land degradation hold both the causes and the solutions to the problem.

B. FACTORS AFFECTING LAND DEGRADATION

The following section will discuss the main causes and pressures of land degradation in the ESCWA region. The fundamental driver of the majority of problems of arid zone degradation around the globe is the rapid increase in human population in recent decades. The increased pressure has led to four main direct causes of desertification: over cultivation, overgrazing, deforestation and salinization of irrigation systems (Goudie, 1996).

Other major root causes, and at the same time consequences, of desertification are poverty and food insecurity combined with unfavourable climatic events such as drought, leading to pressures on often-fragile ecosystems and the adoption of resource depleting survival strategies. However, the driving forces of land degradation are usually related to policy and institutional distortions or failures in the public, government, private, market, civil and/or community sectors, as well as civil strife. The nature of interrelationships and thresholds between these technical, institutional and policy factors at different spatial and temporal scales are poorly understood (FAO, 2002; Blaikie, 1985).

To better describe the interrelationships between the driving forces and pressures of land degradation, the capitals approach is used as an organising principle. The capitals include natural, social, financial/political/institutional, physical/infrastructural and human, and describe generally the realms from which causative forces arise. The driving forces and pressures associated with each of the capitals are described below, however, as there are many interconnections and feedback loops, each pressure will be described following the most common or most influential driving force. Table 1 presents all driving forces and pressures relevant to the ESCWA region.

1. *Natural capital*

The ESCWA region, in general experiences chronic water scarcity and declining quality. Its climatic variability, with periods of drought and/or unreliable rainfall, contributes to the region having the smallest water resource reserves worldwide in absolute terms and per capita (Casas, 1999).

A heterogeneous distribution of renewable water resources (RWR) within and among countries exists, with disparity according to land relief, distance from the sea, latitude and resulting hydro climatic conditions, hydrographical networks and geological structures, and Trans-boundary Rivers.

Table 1. Driving forces and resulting pressures of land degradation in the ESCWA region.

CAP-ITAL	DRIVING FORCES	PRESSURES	SOURCES
Natural	Climatic Variability	Periods of drought or unreliable rainfall	(ESCWA, 2001; Abahussain *et al.*, 2002; ICARDA, 2002; Nielsen and Zöbisch, 2001; UNCCD/ UNDP/GTZ, 2003)
		Chronic water scarcity	(ESCWA, 2001; GM/IFAD, 1998)
		Erosive rainfall events and surface runoff	(UNCCD/UNDP/GTZ, 2003)
		High velocity winds causing dust and creeping sand dunes	(Abahussain *et al.*, 2002; Omar et al., 1998; UNDP/MSEA/UNCCD, 2002)
		Increased water losses through runoff and evapo-transpiration	(Omar et al., 1998)
	Natural disasters	Dust storms and their erosive effect	
		Flash Floods	(UNCCD/UNDP/GTZ, 2003)
		Fire	(Environment, 2004; UNCCD/UNDP/GTZ, 2003; UNDP/MSEA/UNCCD, 2002)
	Adverse Landscape conditions	Terrain roughness (restrictive rapid topographical changes)	(ICARDA, 2002; UNCCD/UNDP/GTZ, 2003)
		Mining, quarrying and extracting activities (e.g. clay)	(MoE, 2004)
		Weak soil structure and texture (compaction, breakage)	(Khresat *et al.*, 1998; Misak *et al.*, 2002; UNCCD/UNDP/GTZ, 2003)
		Agricultural cultivation on marginal land or conversion of rangeland to cropland (due to urbanisation, lack of access, etc.)	(GM/IFAD, 1998; Hussein, 1998; Khresat *et al.*, 1998; Abahussain *et al.*, 2002; ICARDA, 2002; MoE, 2004; Nielsen and Zöbisch, 2001; UNCCD/UNDP/GTZ, 2003)
		Deposition of soil particles and sand	(ICARDA, 2002)
		Depth to water table	(GM/IFAD, 1998; Abahussain *et al.*, 2002; ICARDA, 2002)
	Animal Populations	Pressures by High Animal and/or Livestock Densities (e.g. decreased biomass, soil compaction, etc.)	(ESCWA, 2001; GTZ-CoDeL, 2003; Hussein, 1998; Abahussain *et al.*, 2002; MoE, 2004; Misak *et al.* 2002; Omar et al., 1998; UNDP/MSEA/UNCCD, 2002)
	Primary Productivity	Agricultural Intensification	(ESCWA, 2001; ICARDA, 2002; Nielsen and Zöbisch, 2001; UNCCD/UNDP/GTZ, 2003)
		Increased demands of forest products	(ESCWA, 2001; Abahussain *et al.*, 2002; MoE, 2004)
		Recess of land cover area/increased exposure to erosive forces (including removal of / grazing of crop residues, conversion of naturally vegetated land to croplands)	(ESCWA, 2001; Hussein, 1998; Khresat *et al.*, 1998; ICARDA, 2002; Nielsen and Zöbisch, 2001; Omar et al., 1998; UNCCD/UNDP/GTZ, 2003; UNDP/MSEA/UNCCD, 2002)
		Increased demands of bio-energy / building supplies	(ESCWA, 2001; Omar et al., 1998)
		Decreasing length of fallow period	(ICARDA, 2002; Nielsen and Zöbisch, 2001)
		Nutrient exports ("mining")	(ESCWA, 2001; GM/IFAD, 1998; Khresat *et al.*, 1998; ICARDA, 2002; Nielsen and Zöbisch, 2001)
		Soil organic matter and Carbon depletion	(Khresat *et al.*, 1998)
Social	Conflict and War	Personal safety	(ESCWA, 2001; GTZ-CoDeL, 2003; MoE, 2004; Misak *et al.*, 2002; UNCCD/UNDP/GTZ, 2003)
		Displacement and land abandonment	(ESCWA, 2001; GTZ-CoDeL, 2003; MoE, 2004; Misak *et al.*, 2002; UNCCD/UNDP/GTZ, 2003)
		Pollution and soil structure damage	(ESCWA, 2001; GTZ-CoDeL, 2003; MoE, 2004; Misak *et al.*, 2002; UNCCD/UNDP/GTZ, 2003)
	Food insecurity	Crop yield decreases	(Khresat *et al.*, 1998; Nielsen and Zöbisch, 2001)
	Water insecurity	Water availability /demand per capita	(GM/IFAD, 1998; UNCCD/UNDP/GTZ, 2003)
		Deterioration of water quality (increased turbidity/contamination)	(ICARDA, 2002)

CAP-ITAL	DRIVING FORCES	PRESSURES	SOURCES
	Energy insecurity	Affordability and accessibility to main energy source (unfavourable to biomass)	(UNCCD/UNDP/GTZ, 2003)
	Loss of opportunity	Migration (permanent/seasonal)	(ESCWA, 2001; GM/IFAD, 1998)
		Poverty and disparity between rural and urban incomes/physical infrastructure	(ESCWA, 2001; GM/IFAD, 1998; UNCCD/FAO/UNDP, 2000)
		Land tenure constraints (type, access)	(UNCCD/UNDP/GTZ, 2003)
	Demographic changes	Population growth / density (higher demands on resources)	(ESCWA, 2001; GM/IFAD, 1998; Abahussain *et al.*, 2002; Misak *et al.* 2002; Nielsen and Zöbisch, 2001; UNCCD/FAO/UNDP, 2000; UNCCD/UNDP/GTZ, 2003; UNDP/MSEA/UNCCD. 2002)
		Lack of involvement of women	(ESCWA, 2001.)
		Unemployment rate	(GM/IFAD, 1998)
		Changing consumption patterns and life styles	(Abahussain *et al.*, 2002; UNCCD/FAO/UNDP, 2000; UNDP/MSEA/UNCCD. 2002)
Financial / Political / Institutional	Access	Credit availability (lack of)	(UNCCD/UNDP/GTZ, 2003)
	Land Tenure	Uncertainty of land tenure	(UNCCD/FAO/UNDP, 2000)
		Unregulated, unrestricted use of common lands (i.e. for grazing)	
	Land Policies	Incentives for certain land use types or intensive farming practices	(ESCWA, 2001.)
		Lack of or inappropriate planning and zoning of land use and development	(GTZ-CoDeL, 2003; UNCCD/FAO/UNDP, 2000; UNCCD/UNDP/GTZ, 2003)
		Absence of /non-enforced by-laws on land-use/ protection/ resource management	(GTZ-CoDeL, 2003; Abahussain *et al.*, 2002; UNCCD/FAO/UNDP, 2000; UNCCD/UNDP/GTZ, 2003)
		Legislation for natural resource management (absent or non-enforced)	(UNCCD/FAO/UNDP, 2000)
	Macro-economic policies	Trade agreements and barriers unfavourable to small, self-sustaining (non-export) farmers, or limiting export/import opportunities	(ESCWA, 2001; Nielsen and Zöbisch, 2001; UNCCD/UNDP/GTZ, 2003)
		Trade liberalization	(ESCWA, 2001.)
		Foreign Debt	(UNCCD/UNDP/GTZ, 2003)
		Structural adjustments (removal of subsidies, increased competition for small scale farmers)	(ESCWA, 2001; UNCCD/UNDP/GTZ, 2003)
	Institutional support	Limited public participation in decision-making	(ESCWA, 2001; GM/IFAD, 1998; UNCCD/FAO/UNDP, 2000; UNCCD/UNDP/GTZ, 2003)
		Lack of knowledge of institutional frameworks and support	(ESCWA, 2001; UNCCD/UNDP/GTZ, 2003)
		Lack of availability of extension services/agricultural education	(MoE, 2004; UNCCD/UNDP/GTZ, 2003)
		Absence or weak natural resource institutions (especially at local/rural level)	(UNCCD/FAO/UNDP, 2000; UNCCD/UNDP/GTZ, 2003)
Physical	Water	Lack of runoff control structures	(Khresat *et al*, 1998)
		Irrigation management inappropriate	(UNCCD/UNDP/GTZ, 2003)
	Solid Waste	Waste management	(ESCWA, 2001; UNCCD/UNDP/GTZ, 2003)
		Sewage pollution	(UNCCD/UNDP/GTZ, 2003)
	Housing	Urban expansion	(ESCWA, 2001; GM/IFAD, 1998; Khresat *et al.*, 1998; MoE, 2004; UNCCD/UNDP/GTZ, 2003)
Human	Education/Skills/Knowledge	Lack of awareness of environmental issues and personal impact	(UNDP/MSEA/UNCCD. 2002)
	Culture	Lack of land stewardship	

Table 1. Driving forces and resulting pressures of land degradation in the ESCWA region

Jordan and the Arabian Peninsula countries suffer severe water scarcity with a total (internal and external) RWR below the absolute "poverty threshold" of 500 m3/capita/year (refer to Table 2). The situation is slightly better in Egypt because of its external RWR. The other countries enjoy a more or less favourable situation (total RWR exceeding 1000 m3/capita/year (the minimum requirement); among these Iraq and Syria are highly dependent on external RWR through trans-boundary rivers, with increasing tensions between neighbouring countries over the use of international rivers and aquifers (Casas, 1999).

In many countries, the water deficit is compensated by overdrawing or mining groundwater beyond sustainable limits. In most countries there has been an intensification of water withdrawals through building of dams/reservoirs and capturing or pumping renewable or fossil groundwater. The annual quantity of water used varies from country to country, from hardly 150 m3/capita/year (Jordan) to more than 1,100 m3/capita/year (Egypt). Annual withdrawals, as a percent of the annual average RWR, already exceeded, In 1999, 50% in some countries (Egypt and Syria), or even 100% in Jordan (Casas, 1999). The result is a decline in water levels and increased salinity, particularly in the coastal areas, where seawater intrusion into freshwater aquifers has been reported (GM/IFAD, 1998; Abahussain et al., 2002; ICARDA, 2002).

Country	Total RWR (km^3)				Fossil WR (km^3)	Population (million)			RWR per capita (m^3/year)		
	Internal RWR a	External RWR b	Total RWR c= a+b	Dependency ratio (b/c = % external)		1980	2000	2025	1980	2000	2025
Bahrain	0.004	0.1	0.1	97	0.01	0.29	0.64	1.0	340	160	100
Egypt	1.8	55.5	57.3	97	3.4	40.9	66	94	1400	870	610
Iraq	35.2	40.2	75.4	53	2	13	26.2	46	5800	2880	1630
Jordan	0.7	0.2	0.9	23	0.3	2.9	6	11	310	150	80
Kuwait	0	0.02	0.02	100	0.16	1.37	2.7	*2.8*	150	75	*70*
Lebanon	4.8	0	4.8	0	3	2.7	3.3	4.5	1780	1460	1070
Oman	1	0	1	0	1	0.99	2.3	4.7	1010	430	210
Qatar	0.05	0.-	0.05	4	0.06	0.21	0.6	*0.7*	240	85	70
Saudi Arabia	2.4	0	2.4	0	0.02	9.4	20.1	40	260	120	60
Syria	7	19.2	26.2	80	5.6	8.7	17.9	35	3010	1220	740
UAE	0.15	0	0.15	0	0.1	0.75	2.0	2.8	200	75	55
Yemen	4.1	0	4.1	0	1.4	8.2	16.4	43	500	250	95
TOTAL	**57.2**	**115.22**	**172.42**	**37.83 (average)**	**17.05**	**89.41**	**164.14**	**285.5**	**15000**	**7775**	**4790**

Table 2. Renewable Water Resources (RWR) (Casas, 1999)
Italics: Approximate data. ...: Data not available. °: Rounded numbers. 0.–: Minimal (almost zero).
a. Internal RWR: internal surface water + internal groundwater – overlap.
b. External RWR: external surface water + external groundwater.

Erosion by wind and water is a major problem in the area (Khresat et al., 1998). The region experiences wide variations in rainfall, regionally and seasonally, and receive high intensity rainfall events that cause flash floods and soil erosion (UNCCD/UNDP/GTZ, 2003). During dry periods, high velocity winds cause dust storms and creeping sand dunes. The dry conditions also encourage uncontrolled forest and grassland fires ((Environment, 2004; UNCCD/UNDP/GTZ, 2003; UNDP/MSEA/UNCCD, 2002)

The adverse landscape conditions of the area contribute to land degrading processes. Terrain roughness (i.e. steep slopes) limits the area of arable land, encouraging deforestation, conversion of rangeland to cropland and use of marginal lands for agriculture, often with unsuitable agricultural practices (UNCCD/UNDP/GTZ, 2003). In the ESCWA region, arable land represents only approximately 4% of the total area, ranging from less than 2% of the Arabian Peninsula to 33% of Lebanon, refer to Table 3. Arable land per capita is very limited; the region currently has an average of 0.33 ha of arable land per capita. Some countries such as Jordan, and most of the Arabian Peninsula countries are already in a particularly critical situation, with less than 0.1 ha of low-production-potential arable land per capita (semi-arid climate with poor irrigation potentiality).

Country	Land Resources (million ha) (1996)				Population			Arable Area per Capita (ha)			Agricult. Labour Force (ALF)		Arable Area/ Labourer (ha)	
	Total	Arable Area	Irrig.	Perm. Pasture	1980	2000	2025	1980	2000	2025	1980	1996	1980	1996
Bahrain	0.07	0.004	0.003	0.004	0.29	0.64	1.0	0.1	0.06	0.04	...	0.004	...	1
Egypt	100	3.3	3.3	0	40.9	66	94	0.08	0.05	0.04	5.1	8.4	0.65	0.4
Iraq	43	5.8	3.5	4	13	26.2	46	0.45	0.22	0.13	1.1	0.7	5.3	8.3
Jordan	8.9	0.4	0.08	0.8	2.9	6	11	0.14	0.07	0.04	*0.7*	0.16	0.6	2.5
Kuwait	1.8	0.005	0.004	0.1	1.37	2.7	*2.8*	0.003	0.01	0.01	...	0.007	...	0.7
Lebanon	1.0	0.3	0.1	0	2.7	3.3	4.5	0.11	0.09	0.07	0.1	*0.05*	3	6
Oman	21	0.06	0.06	1	0.99	2.3	4.7	0.06	0.03	0.01	0.14	0.25	0.42	0.24
Qatar	1	0.02	0.01	0.05	0.21	0.6	*0.7*	0.1	0.03	0.02	...	0.006	...	3.3
Saudi Arabia	215	3.8	1.5	120	9.4	20.1	40	0.40	0.19	0.10	1.3	0.8	2.9	4.8
Syria	18.5	5.2	1.1	9.3	8.7	17.9	35	0.60	0.29	0.15	0.8	1.3	6.5	4
UAE	8	0.07	0.07	0.2	0.75	2.0	2.8	0.09	0.04	0.03	...	0.07	...	1
Yemen	53	1.5	0.49	16	8.2	16.4	43	0.18	0.09	0.03	1.2	2.7	1.3	0.7
AVG								**0.193**	**0.098**	**0.056**			**2.58**	**2.75**
TOTAL	**471.27**	**20.46**	**10.22**	**151.45**	**89.41**	**164.14**	**285.50**				**10.44**	**14.45**		

Table 3. Land Resources (Casas, 1999) *Italics*: Approximate data. ...: Data not available.

Permanent pastures and rangelands, which cover approximately 30% of the total area and provide around one-third of the diet of livestock (Casas, 1999), are severely degraded in most countries due, in part, to unrestricted grazing. The recess of land cover, due to overgrazing of rangelands or the removal of crop residues for animal consumption increases soil exposure to erosive forces (Hussein, 1998). In Lebanon, soil erosion, due to increased cultivation of marginal lands & poor management of rangelands, has resulted in between 5-50 tons per hectare of soil loss annually on 130 million hectares of degenerated rangelands (UNCCD/UNDP/GTZ, 2003). Additionally, overgrazing has destabilized sand dunes causing them to drift and lose productivity.

Deforestation, and the resulting problems of erosion, loss of water retention and biodiversity, is major problems in most of the region. Caused primarily (in addition to naturally-occurring forest fires) by the need for agricultural land, increased demands for bio-energy (fuelwood and charcoal) and building supplies has led to overexploitation of woody resources (UNCCD/UNDP/GTZ, 2003). In Syria, 3000 hectares of forest have been converted to agricultural lands in the past 15 years (UNDP/MSEA/UNCCD, 2002).

Soil erosion is a major form of land degradation in the region, in part due to its structure and texture. The weak structure and texture of dryland soils lead to soil compaction and sealing, which are considered the most significant mechanisms of land degradation in Kuwait (Al-Dousari *et al.*, 2000). Compaction and sealing or crusting cause adverse changes in the water infiltration rate, bulk density and soil strength, reducing soil productivity. Moreover, soil development processes are much slower than the rate of losses in desert areas where high-speed winds are common and the evapotranspiration rates are high (Omar et al., 1998).

In response to the shortage of arable land, agricultural intensification has been encouraged, resulting in intensive cropping on marginal land and conventional tillage (Hussein, 1998). Technological changes from animal traction and hand harvesting to less labour and time intensive practices with tractors and harvesters have reduced fallow periods in most of the region (Nielsen and Zöbisch, 2001). Continuous cropping, in many cases without supplying nutrients through fertilization has depleted nutrients from soils of the region (Khresat *et al.*, 1998). On the other hand, the use of chemical fertilizers and weed control, when mismanaged, has caused salinization in marginally productive drylands (and some fertile lands) in Lebanon (UNCCD/UNDP/GTZ, 2003)

2. *Social capital*

The occurrences of conflict, civil unrest and war have plagued the region for decades, having a tremendous impact on the state of degradation, through human displacement, land abandonment, pollution and lack of enforcement of regulations. The civil war in Lebanon (1975-1990) resulted in all of the above-mentioned consequences (UNCCD/UNDP/GTZ, 2003). As a result of the Iraqi occupation and the Gulf War (1990–1991), the war machinery and ground fortifications have affected Kuwait's desert intensely. At least 70 per cent of the desert ecosystem suffers some degree of land degradation, including degradation of vegetation cover; soil disturbance; exposure and desegregation of near surface sediments; landscape disruption; soil compaction; and pollution by oil and explosives, resulting in a reduction of the soil infiltration capacity by at least 50 per cent (Misak *et al*, 2002).

Poverty and insecurity of basic necessities (i.e. food, water and energy sources) lead, out of necessity, to the adoption of resource depleting strategies. Thus economic activities, poverty and the disparity between rural and urban incomes and physical infrastructure must be considered in any analysis of land degradation.

According strictly to their parity GDP per capita, the rich countries (parity GDP per capita higher than US$ 8,000) are large oil-exporting countries with small populations, including Bahrain, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates. All the other countries (except Yemen which is low-income, less than US$ 1,500) are generally considered as medium-income countries (Casas, 1999).

According to the classification used by Casas (1999), which incorporates the UNDP "human development index" (HDI), taking into account life expectancy/longevity, education (adult literacy rate; rate of education at primary, secondary and university level), and parity GDP per capita, countries with high income per capita and high human development (>0.8) are Bahrain, Kuwait and Qatar; countries with high income per capita and medium human development (0.79>0.5) are Oman (with the notably low 8% of population poor) and Saudi Arabia. Countries with medium income per capita and medium human development are Egypt, Iraq, Jordan, Lebanon and Syria. Yemen is the only country with low income per capita and low human development (<0.5). Table 4 displays this socioeconomic data for all countries of the ESCWA region.

Population growth and density are of paramount importance to understanding the land degradation processes operating in a given area. The region in general is experiencing rapid population growth and urbanisation, but with great variance between individual countries. Refer to Table 5 for figures for each country in the region. The average total population increase between 1995 and 2000 was 2.7% per year for the region, ranging from 1.8% in Lebanon and Qatar to 4.2% in Oman. The annual rate of urbanisation between 1994 and 2000 for the region was on average 3.7%, ranging widely from 0.5% in Kuwait to 7.7% in Oman. In most of the region (according to 1996 data), the urban population has surpassed the rural population, (exceptions include Egypt, Oman and Yemen) with the rural population representing 30% of the population (Casas, 1999).

A high migration rate from rural areas (mostly from impoverished low rainfall rural areas) to the urban centres (mostly to informal urban settlements) is increasingly being felt in the region (ESCWA, 2001). This has led to increasing rural poverty as the growing population exploits a declining natural resource base (exacerbated by the expansion of urban centres on to agricultural lands). In some cases, farmers have been driven onto poorer quality lands, generating lower incomes, and encouraging desertification processes. The future implications of these trends for land use, farm and flock size, income from agriculture and the cost of labour will have far-reaching effects on the low rainfall areas of the sub-region (ESCWA, 2001).

Country	Total Popu-lation 1996 (million)	Gross Domestic Product (GDP) 1996					Human Development Index 1994	Total Poverty 1992 (% of population)	Rural Poverty 1992 (% of poor living in rural areas)
		GDP (billion USD)	GDP/cap (USD)	Parity income coeffic.°	Parity GDPa (billion USD)	Parity GDP/cap (USD)°			
Bahrain	0.57	4.5	7890	1.7	7.7	13400	0.87	23	0
Egypt	63.2	67.9	1070	3.6	244	3850	0.61	22	61
Iraq	20.6	26.4	*1280*	*2.5*	*66*	*3200*	*0.53*	*24*	*34*
Jordan	4.4	7.2	1640	2.5	18	4100	0.73	17	29
Kuwait	1.7	35.4	21100	1.1	39	23200	0.84	22	6
Lebanon	*3.1*	*13.3*	*4360*	*1.1*	*15*	*4800*	0.79	20	17
Oman	2.3	10.8	4700	1.7	18	7990	0.72	8	64
Qatar	0.56	6.5	11600	1.5	9.8	17400	0.84	25	28
Saudi Arabia	*18.8*	138	7300	1.3	179	9600	0.77	24	34
Syria	14.6	*16.4*	1120	4.8	79	5380	0.76	39	68
United Arab Emirates	2.26	36.3	16100	1.0	36	16100	0.87	23	24
Yemen	15.7	5.3	340	3.1	16	1050	0.36	27	72
AVERAGE			**6541.67**	**2.16**	**60.63**	**9172.5**	**0.72**	**22.83**	**36.42**
TOTAL	**147.79**	**368**							

Table 4. Socioeconomic Data (Casas, 1999) Notes: *Italics*: Approximate data. °: Rounded numbers.

Country	**Total Population**			**Annual Rate of Urbanization 1994-2000**	**Rural Population (1996)**	
	1980	**1996**	**Increase (1995-2000)**			
	Million	**Million**	**% per year**	**%**	**Million**	**%**
Bahrain	0.29	0.57	2.2	2.9	0.1°	9
Egypt	40.9	63.2	1.9	2.6	34.8	55
Iraq	13	20.6	2.8	3.6	2.5	25
Jordan	2.9	4.4	3.3	4.7	1.2	27
Kuwait	1.37	1.7	3.0	0.5	0.–	2
Lebanon	2.7	*3.1*	*1.8*	2.9	*0.4*	12
Oman	0.99	2.3	4.2	7.7	2°	85
Qatar	0.21	0.56	1.8	2.2	0.–	8
Saudi Arabia	9.4	*18.8*	*3.4*	*3.6*	*3.6*	*19*
Syria	8.7	14.6	2.5	4.4	*6.9*	*47*
United Arab Emirates	0.75	2.26	2.0	2.7	0.3	15
Yemen	8.2	15.7	3.7	6.6	10.2	65
AVERAGE			**2.72**	**3.7**		**30.75**
TOTAL	**89.41**	**147.79**			**59.9**	

Table 5. Total population, rural population and urbanization (Casas, 1999)
Note: *Italics*: Approximate data. °: Rounded numbers. 0.–: Minimal (almost zero)

Other social problems driving land degradation are the lack of involvement of women in planning and decision-making (ESCWA, 2001), the high unemployment rate, the increasing incidence of poverty and sharp disparities between rural and urban incomes and social and physical infrastructure (ESCWA, 2001), and changing consumption patterns and life styles (Abahussain *et al.*, 2002; UNCCD/FAO/UNDP, 2000; UNDP/MSEA/UNCCD, 2002).

3. *Financial / Political / Institutional capital*

The financial, political and institutional drivers of land degrading processes are many and generally represent the key to overcoming the pressures on land resources. Causative factors include the lack of access to credit or specifically agricultural credit schemes (UNCCD/UNDP/GTZ, 2003); land fragmentation due to inheritance laws and the high transactional costs; disabling land tenure systems; absence of land use planning (particularly in post-war development and construction); absence or lack of enforcement of policies and plans for water and agriculture (UNCCD/UNDP/GTZ, 2003).

During and immediately after the war in Lebanon (for example), development planning was lacking, allowing uncontrolled development and exploitation of natural resources. The lack of supervision and planning for land use and inadequate institutional structures for issuing rules and ensuring adherence to the rules, has resulted in inappropriate land uses being practiced for the climate, physical geography, socio-economic and ecological conditions, including extensive building in rural areas, leading to accelerated deforestation, inappropriate use of pastures and increased land degradation (GTZ-CoDeL, 2003).

The persistent instability in and around the countries of the region has led Governments to adopt strict national policies for food security. These policies have led to the application of large-scale agricultural protectionism, subsidized pricing for agricultural inputs and products and the imposition of trade barriers. Heavily subsidized agrochemicals and irrigation water, have severely affected the water and land resources and created unsustainable patterns of agricultural production (ESCWA, 2001). Some countries in the region have adopted improved production technologies, which have resulted in higher food (mostly cereal) production. However, the technologies have not widely reached the poor farmers who need them most (ESCWA, 2001).

Most countries in the region have, to varying degrees, pursued structural adjustments, market liberalization and deregulation policies. However, most countries (in 2001) had not adjusted their agricultural and land management policies to benefit from the opportunities created by the widespread development of competitive global markets. As trade barriers are lowered and environmental standards enforced, many agricultural producers are facing increasing competition while trying to cope with declining support and loss of subsidies (ESCWA, 2001; UNCCD/UNDP/GTZ, 2003).

Centralised decision-making and limited public participation in decision-making, policy planning and implementation, particularly by women and youth, resource users (including farmers, pastoralists and their representative organisation), contributes to a culture of non-involvement in environmental and development issues. A lack of availability of extension services/agricultural education and weak natural resource institutions (especially at local/rural level) contribute to this problem as well. The development of clear environmental standards and indicators is crucial for increasing the awareness, commitment, and participation of the natural resource users in the process of promoting sustainability of natural resources (ESCWA, 2001; UNCCD/UNDP/GTZ, 2003).

4. *Physical and infrastructural capital*

A lack of infrastructure, particularly in rural areas, for water control and harvesting, irrigation management, solid waste disposal, sewage containment and/or treatment, and housing for controlled expansion, increases the likelihood of degradation of the land and water resources.

Many countries in the region have poor water-use efficiency. Agriculture, which is by far the largest consumer of water (using around 80% of the water withdrawn in the region), is also probably the least efficient sector, with water losses of more than 60% in irrigation caused by physical and economic mismanagement (poor maintenance/performance of the irrigation/drainage systems, poor distribution and on-farm application, water priced much below the real costs, private open access to aquifers, etc.). Water degradation and pollution (pathogen and organic matter, nitrates, salt, heavy metals, etc.) originating from agricultural, domestic, and industrial activities have been increasing over the years (Casas, 1999).

Salt damage to irrigated land is extensive and a chronic problem, caused mainly by irrational use of irrigation water and poor management, leading to salinization, water-logging, alkalization and nutrient depletion in large areas (ESCWA, 2001).

5. *Human capital*

The main issues of land degradation that relate to the human capital are the general lack of awareness of environmental issues and personal impact, which relates to (and was discussed in regards to) the lack of involvement in institutional decision-making and the culture of land stewardship.

C. CHARACTERIZATION AND EFFECTS

The following section will characterize the state of the region, including the types, extent and severity of land degradation, and discuss the impacts that land degradation has on the livelihoods of people in the region.

1. Characterisation of the state of land degradation in the ESCWA region

Land degradation in the ESCWA region is generally widespread and severe. The land degradation processes present are physical, chemical and biological in nature, and include: soil erosion by water (sheet, rill and gully), soil erosion by wind (sheet erosion), soil compaction, soil crusting and sealing, sediment and dust deposition, water contaminated by eroded materials; soil nutrient and fertility depletion, salinity, toxic compounds (pollutants in soil matrix); loss of land cover & biomass, loss of organic matter and a loss of biological diversity.

Wind erosion is considered by Abahussain *et al.*, (2002) to be the most common environmental problem in the region. It leads to the removal of fertile topsoils and the encroachment and accumulation of sands on productive rangelands and agricultural land, urban areas and civil construction. Barth (1999) observed in Saudi Arabia, exposed roots, giant sand ripples, changes in the extension of inland sabkhas and new active dunes as a result of wind erosion.

Water erosion contributes to the loss of fertile topsoils; accumulation of eroded material behind dams (siltation) in irrigation networks and on productive rangelands and agricultural lands (Abahussain *et al.*, 2002). In some extreme cases, the runoff has triggered mudslides and flooding (MoE, 2004). Loss of soil nutrients and organic matter results in a decline in fertility and thus in land productivity (Abahussain *et al.*, 2002). A loss of biodiversity of fauna and flora has been observed in Lebanon (MoE, 2004).

Salinization and water logging leads to the accumulation of salts in irrigated lands, resulting in an annual loss of large tracts of valuable cropland due to rising water table levels. The leaching of excess salts increases water consumption, thereby putting additional pressure on the limited water resources (Abahussain *et al.*, 2002). Declining surface water levels and increased salinity, particularly in the coastal areas, where seawater intrusion into freshwater aquifers have been noted (GM/IFAD, 1998).

Soil and water pollution is widespread due to inappropriate soil management and extensive use of fertilizers and pesticides in irrigated areas. Accumulation of pollutants on the soil surface layer of agricultural areas close to industrial complexes, and accumulation of polluting materials in both land and water resources due to hostilities (wars) in the region during the last five decades have been noted (Abahussain *et al.*, 2002). Marine pollution and degradation of coastal and marine environments have been observed, as well as seawater intrusion into freshwater aquifers (ESCWA, 2001)

2. *Impacts of land degradation*

The cumulative impacts of land degradation are a deterioration or loss of livelihoods, an increased prevalence of poverty and substantial economic loss from local to national levels. The aggregate impacts include water insecurity (scarcity and contamination), health problems (due to inadequate quantity and quality of water and nutrition), food insecurity, income insecurity and decreased purchasing capacity, energy insecurity and an erosion of social structures and cultural values. These impacts are a result of water scarcity for human use and consumption and for crop and livestock production, reduced crop yields due to soil productivity decline, and the damage to forest and range lands in the region, decreases in energy sources through loss of biomass and through dam siltation due to sediment runoff.

III. REVIEW OF APPROACHES, METHODS AND MODELS FOR ASSESSING LAND DEGRADATION

Land degradation is a broad multidimensional issue that has been studied for a range of purposes using a variety of approaches. The scope, focus and scale of study are generally purpose driven, and determine the methods and technologies used for data collection and analysis.

This chapter will characterise and discuss common approaches, methods and models to assess land degradation, both in general and those applied in the ESCWA region and in other regions/countries when relevant, and discuss the positive attributes and limitations of each.

But first an understanding of the dimensions of land degradation studies and analysis must be established, upon which the assessment of methods may be based. The following section will describe the general issues of approaches, scope, scale and purpose.

A. CHALLENGES FOR ASSESSMENT OF LAND DEGRADATION

The study of land degradation can be quite complicated and limited by several factors. The main issues are the definition of land degradation, the complexity of causes and processes of land degradation, the temporal changes of degradation, and the spatial scale for study.

Firstly, land degradation is a very broad subject area; its scope can include both naturally occurring and human-induced land degradation (which can even appear to the same in form and function, just differing in their causes). Further, the definitions of land and soil must be considered, does it include water, air, etc.? The researcher must clearly define the scope of land degradation to be studied and be aware and mindful of the scope covered in other research materials.

There are many processes that lead to a state of land degradation. The processes have different driving forces and promoters that are physical, biological, social, economic, and/or infrastructural in nature. Many feedback loops may occur in the chains of causation and response. Thus, the study and assessment of land degradation can be a complex proposition that may limit the ability for comprehensive holistic study. There must be a balance between accurately representing reality in a holistic and integrative manner and maintaining a manageable level of complexity.

The biophysical processes of land degradation have been the attention and focus of natural scientists for many years. Yet, the human, social, economic and cultural dimensions of land degradation have been less studied and poorly understood. Even less understood are the linkages between the biophysical processes and the socio-economic factors, driving forces and pressures that cause land degradation.

Approaches differ widely, depending on the intended purpose in terms of the temporal timeframe to be studied. Medium to long-term monitoring of land degradation trends of change over time differ from the generally more detailed, large-scale studies that provide a 'picture in time' of the current state of land degradation.

The temporal issues of land degradation need to be explored when considering the merits of study approaches. Generally the state of land degradation changes over time, but some environments, particularly those in the absence of human-induced pressures, can become stable in their degraded state, necessitating an approach that can distinguish lands currently experiencing degrading processes from those that are stably degraded. In regards to judgements needed when assessing land degradation, some processes have long been occurring, thus assigning a standard to which the present condition may be judged can be rather subjective.

A distinguish between approach and methods is required, an approach can incorporate any number of methods, it orients and defines the scope and scale of study whereas methods are the actual procedures employed for data collection and analysis to achieve the objectives of the study.

B. MAIN APPROACHES, METHODS AND MODELS

The inventory of degraded lands is an essential first stage to address desertification causes, impacts and solutions. However, there is to date, no commonly accepted method to assess land degradation, in all of its forms and extents that also link the social and economic drivers or promoters of land degradation.

Current land degradation assessment methods are piecemeal in nature and tend to focus on the biophysical aspects. These provide estimates of the intensity and extent of individual types of land degradation, but are lacking in their ability to identify the driving forces and causes of land degradation processes amongst the social, economic, cultural and demographic factors.

It is now commonly accepted that a comprehensive, holistic approach for the study of land degradation provides information that is far more useful to land managers, policy makers, extension workers, etc. than a compartmentalized partial assessment of land degradation (for example of only one process of land degradation, e.g. soil erosion). Of late, soil and land degradation research and assessment projects have been moving from the rather mechanistic, biophysically oriented methodologies towards a more holistic framework in which biophysical, socio-economic, anthropological and cultural aspects are considered, and stakeholder interests and perspectives are incorporated.

These sentiments are reflected in the recent FAO/UNEP Land Degradation in Dryland Areas (LADA) initiative, which focuses on developing and promoting a holistic approach to land degradation and desertification and recognizes that combating land degradation and desertification requires assessment and monitoring of the type and severity of land degradation, and analysis of the causes of the land degradation that has occurred. Only with such an understanding can appropriate actions to counter the problem be selected and applied.

In 2002, as part of the LADA project, van Lynden and Kuhlman reviewed the existing methods for land degradation assessment. A variety of methods were examined and evaluated to determine their usefulness for the LADA project. The methods include:

- Expert Opinion (subjective assessment)
- Remote Sensing-based methods (satellite imagery and aerial photographs, linked with ground observations)
- Field monitoring (stratified sampling and analysis and long-term field observation)
- Productivity changes (observation of changes in crop yields and livestock output)
- Land users' opinion / field criteria (farm-level studies on a sample basis)
- Modelling (prediction of degradation hazard and for extrapolating the results on observed degradation)

None of these consist of a single methodology, but mostly indicate a broader approach of which several variations have been applied. An overview of the features of each of these methods, as described by van Lynden and Kuhlman (2002), is provided in Table 6. The authors make the following recommendations for the use of these methods. Degradation hot spots could be identified in a generic small-scale assessment with the use of a combination of expert opinion and remote sensing. The identified degradation type(s) of the hot spots could be further explored using more detailed and location-specific methodologies such as field monitoring, assessing productivity changes and land users opinion. Existing models can at times be used for extrapolating the results of the latter to areas with similar conditions not directly covered by these methodologies.

The potential and limitations of the reviewed methods for land degradation assessment were discussed. In general, the major limiting factors of assessment methodologies, besides geographical coverage and scale, is the range of degradation issues that the assessment method attempts to address and the specificity of discipline orientation. For instance, a method designed to look into the nutrient depletion aspect of land degradation does not make any linkages with different but related aspects of degradation such as land cover changes. The methods are fragmented and represent only partial views of a complex multifaceted process.

Method / Features	Expert opinion	Remote Sensing	Field monitoring	Productivity changes	Land users opinion/ field criteria	Modelling
Applicability/ adaptability	Flexible	Vegetation, soil, terrain, etc.	Flexible: soil, vegetation, …; status (direct); risk (derived).	Yields, production; trends	Flexible	Flexible
Scale	Any, but most appropriate for small scale	Any, but most appropriate for small scale	Local	Local	Local	Local (mostly) to global
User-friendliness	High	Low	Medium	Medium	High	Medium
Costs per unit area	Low	Medium	High	High	Medium - high	Variable
Outputs	Spatial / point	Spatial	Point	Point	Point	Point/spatial
Replicability	Low	High	High	High	Low-medium	High
Comparability/ Compatibility	Low	High	Medium	Medium	Low	Variable
Subjectivity	High	Low	Low	Medium	High	Low
Stakeholders involvement	Variable	Low	High	High	High	Low
Socio-economic issues	Low	Low	Medium	High	High	Medium
Overall	Good method for quick first overview, reconnaissance	Stand alone assessment or to complement other methods.	"Hard" local data, can complement other methods	Information on impact of degradation	Perception of local stakeholders	Scientific understanding of process

Table 6. Characterization of land degradation assessment methods (van Lynden and Kuhlman, 2002).

Recognizing that land degradation includes a wide range of issues and is the result of a series of complex processes, there is an inevitable trade-off between comprehensiveness of the methodology and the user-friendliness of it. Assessments are at risk of being either, very generic so that they are easy to apply, or overwhelmingly complex. However, it was noted that the frequently observed desire to have "simple" assessment methods is not entirely realistic. The results of such an assessment would be limited to applications for informative and educational tools, however when results are intended for use in planning and decision-making regarding remediation – instances where detailed and accurate data is required – a more detailed assessment is required, regardless of the complexity.

The importance of methodological integration cannot be overemphasized. The integrative nature of any methodological framework needs to look at integration not only form the discipline-oriented standpoint, but also integration of the cyclic nature of degradation processes, incorporating issues leading to, and consequence of, the land degradation process. There is a decided biophysical bias in most current land degradation assessment methods and a weakness with regards to assessing the socio-economic, demographic, and gender issues of land degradation.

In their review, Van Lynden and Kuhlman (2002) concluded that at that time no ready-developed methodology was available for off-the-shelf application to assess all aspects of land degradation. In response to these findings, FAO commissioned, through a consultancy, the development of a comprehensive framework approach to land degradation assessment in dryland areas. The consultancy report (Ponce-Hernandez, 2002) describes a holistic and integrative approach to assess the physical, biological, social, economic and infrastructural issues related to land degradation in dryland areas that is based on a modified pressure-state-response model that incorporates too the driving forces and impacts of land degradation. The approach attempts to provide a multi-scalar, comprehensive assessment using a "toolbox" of methods to be selected from and combined as relevant to the conditions of the study area.

ICARDA (2002) undertook a soil/land suitability classification study in Syria at three levels of detail: reconnaissance, semi-detailed survey, and a detailed survey, using participatory techniques. Changes in settlement pattern, land cover and use, gully patterns and wind deposition were observed using a time series of aerial photographs and Landsat satellite imagery. This exercise was complemented with field observations of visual indicators of land degradation, and interviews with farmers. The combination of these information sources provides indirect evidence of decline in fertility and productive capacity, a widespread form of land degradation.

Eswaran and Reich (1998) assessed the vulnerability of land resources to desertification using spatial databases on global biophysical resources and climate incorporated in a GIS. Soil units on the world map were empirically assigned to vulnerability classes based on the following considerations (although exact procedures are not provided in the paper):

- Coefficient of variability of rainfall – vulnerability increases with increasing coefficient;
- Depth of soil including presence of impermeable layers;
- Extreme levels of chemical and physical conditions;
- Resilience of soil – to recover from mismanagement;
- Information incorporated in soil classification term.

Published reports of degradation were used to validate or "ground-truth" specific locations on the map. The final map displays the areas assigned to each class of vulnerability at a scale of 1:30,000,000. Eswaran *et al* (1998), furthered this method with the use of published information on land resource constraints to produce derivative maps of major land resource stresses, land quality, and susceptibility to wind and water erosion that were combined with the vulnerability to desertification assessment. For Africa and Asia, the analysis of risk of desertification was coupled with studies on population density using an interpolated population database and further, was related to serious conflicts in countries.

GTZ-CoDeL (2003) developed, and applied in Lebanon, a systematic approach for identifying desertification prone areas and classifying their levels of sensitivity in order to highlight 'hot-spots' and prioritise areas in need of remedial action. In general, the approach is based on indicators combining subjective and objective criteria and involving only the major factors causing desertification. The approach follows six basic steps for defining desertification prone areas:

1. Identify the indices and necessary data considering four elements: correlation to degradation or environmental state; data availability; extrapolation potential from existing data; ability to update the information for monitoring purposes.
2. List the indicators and relevant data sources and the relationships connecting data and indicators.
3. Map initial data layers.
4. Re-classify each initial layer, giving a value of 1 to components that contribute least to desertification, and 2 to those contributing most (layers with more than 2 classes of values are given values equally distributed between 1 and 2).

5. Calculate each index (made up of one or more relevant data layers) using the reclassified values of each data layer, obtaining the geometric mean using: (x = index, n = number of layers) $Index\_x=(layer\_1_x*layer\_2_x*layer\_3_x*...*layer\_n_x)^{(1/n)}$.
6. Calculate the Desertification Prone Areas (DPA), a result of overlaying the indices and calculating the geometric mean: $DPA =(index\_1 * index\_2 * index\_3 * ... * index\_n)^{(1/n)}$.

Five index maps were produced, including the Climatic index map; Soil index map; Demographic pressure index map; Land use intensity index map; Vegetation index map. The relevant data layers for each index map are displayed in Figure 1.

The main advantages of this method is that it is a flexible framework that is relatively easy to apply and to customise, it provides a systematised method for integration of different information layers into a single index, which is replicable, easily updatable, it requires data that are usually available at the national level, using discreet (i.e. land use map, soil map etc.) and continuous data (i.e. rainfall map, topography, etc.) and provides insight into mitigations actions required.

The drawbacks of this approach are its requirement for consistent spatial data, at the same level of spatial detail and scale, its subjective element introduced in the ranking of components by their contribution to land degradation, the equal weighting of indices makes the analysis generic, although modification could easily be made to suit the local conditions (however, again with a trade-off of subjectivity), and finally, it does not include all possible causes of desertification, and thus may be oversimplifying a complex situation in some areas.

Using a hierarchical classification, ICARDA (2002) produced maps of land-use/land-cover change and calculated the areas experiencing individual combinations of change, classes of change and trends in the changes (including land degradation).

The maps were produced using remote sensing tools and products including Advanced Very High Resolution Radiometer (AVHRR) satellite system, which since 1982 has provided continuous monitoring of the world's vegetation cover with a coarse resolution (8 km). It is suggested that AVHRR imagery may be useful in identifying 'hot spots' of land use/land cover change. The method developed by ICARDA overcomes the problems of the system's short time series and low spatial resolution, and the difficulties involved in distinguishing genuine trends in the land cover from short-term fluctuations in biomass (a result of year-to-year weather variations). The Normalized Difference Vegetation Index (NDVI) was calculated and converted into a land use/land cover classification for which there are 2 methods available: (1) a hierarchical decision-tree, based on the average values of the mean and maximum NDVI, to take into account average weather conditions; (2) adjusted NDVI thresholds of the hierarchical decision-tree for different agro-climatic zones, to take into account annual fluctuations of the actual weather.

Using these procedures, annual land-cover maps were produced and condensed into four maps, showing the major land-cover classes. Depending on the value and sequence of the major land-cover types, the following kinds of change were allocated to each pixel: noise; stable land use/land cover; stable land use/land cover mosaic; and change pattern.

Seventeen stable classes were recognized, as well as 66 change patterns. The latter were regrouped into 22 change classes, and four change trends:

- Intensification of agriculture (rainfed to irrigated);
- Intensification of natural vegetation (vegetation biomass/density);
- Retrenchment of agriculture (more-intensive to a less-intensive form);
- Retrenchment of natural vegetation (vegetation biomass/density).

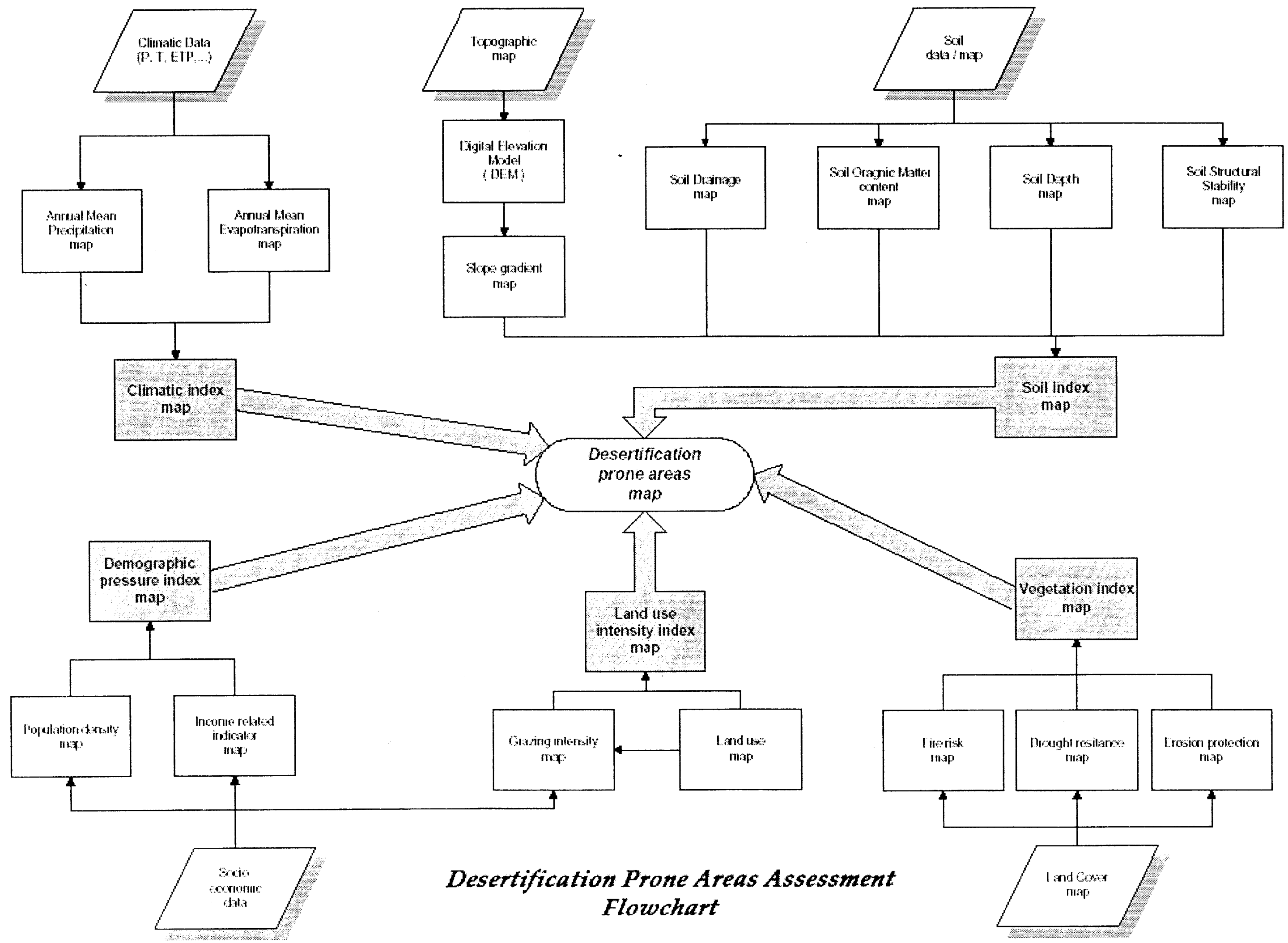


Figure 1. Desertification Prone Areas Assessment Flowchart (GTZ-CoDeL, 2003)

Agricultural intensification and land degradation were the anticipated trends, however, a more complex picture emerged, showing variation in land-use/land-cover change by sub-regions. In most sub-regions intensification of agriculture is a major, if not the predominant trend. The Near East in particular has experienced remarkable intensification of agriculture, mainly through conversion of rainfed into irrigated croplands. However, retrenchment of agriculture and natural vegetation (potential indicators of land degradation) and intensification of natural vegetation are also important trends with differences between sub-regions.

The advantage of this form of 'hot spots' approach is that they can target priority areas, however, due to the low resolution, with little detail. For this reason, 'hot spots' should be, and in this case are, further characterized using ground-based observations complemented with high-resolution satellite imagery (such as Landsat or SPOT).

Kharin *et al.* (1999) assessed the state of land degradation in Asia. Criteria were developed for the assessment and small-scale mapping of each land use type including: forest, rangeland, dry agriculture, irrigated agriculture, and exposed bottom of sea. The types of degradation considered in the assessment and the criteria used to evaluate the type of degradation are listed below. For each criterion, classes (slight, moderate and severe/very severe) were developed using quantitative or qualitative class thresholds.

- Vegetation cover depletion
  - Plant community; % of climax species; decrease of total plant cover; loss of forage on rangeland; loss of current increment of wood; wind erosion - non-arable (percentage of area covered by sand dunes, covered with sod forming plants); wind erosion – arable land (removal of top horizon, blow-outs % of area, loss of yield of main crop);
- Water erosion
  - (Non-arable) type of erosion; % removal of top soil horizon;
  - (Arable) removal of top soil horizon; loss of yield of main crop;
- Soil salinization
  - Soil salinization solid residue %; salinity of ground water; salinity of irrigation water; seasonal salt accumulation; loss of yield;
- Soil salinization caused by the drop of Aral Sea level
  - Change of soil; amount of salts in top 100 cm of soil; change of the vegetative cover;
- Rangeland water logging in Central Asia
  - Depth of fresh ground water; change of dominant plants; plant cover %.

The assessment relied on field observations and remote sensing tools (NOAA/AVHRR) for data collection. NDVI was calculated for each sample plot and the related plot information, including the coordinates, land use type, desertification class and the causes of desertification were recorded in a spatial database. Thematic maps and other publications were used for ground-truthing.

Liu and Yang (2003) used four desertification indicators (vegetative cover, proportion of drifting sand area, desertification rate, and population pressure) to assess the severity of desertification in China using a GIS. The first three factors were derived from multi-temporal remote sensing and land inventory data, population pressures were calculated from census data. Severity classes were developed for each indicator and weights assigned for the assessment. The following formula is proposed for the calculation of the severity of land degradation, the higher the calculated value, the more severe the land degradation is.

$$D_j = \sum_{i=1}^{n} P_{ij} C_i^{-q}$$

Where Dj $(0 \leq Dj \leq 1)$ represents the risk of land degradation in region j; Ci is the rank at which land in an assessment unit has been degraded; Pij refers to the aerial percentage of land having a rank i in relation to the total area of unit j; n is the number of degraded ranks; and q denotes the exponent of rank. An empirical value of 1.5 was adopted for q in the study after experimentation. The calculation was carried out with county/city as the unit. Dj was calculated through a computer program (name not specified by the authors) for both the entire study area and for individual units.

Using selected environmental indicators integrated into GIS, Mouat *et al* (1997) developed a technique for identifying and assessing areas at risk for desertification in the arid, semi-arid, and subhumid regions of the United States. The following five indicators were used:

- Potential erosion;
- Grazing pressure as defined by AUMs/carrying capacity;
- Climatic stress (expressed as a function of changes in the Palmer Drought Severity Index [PDSI]);
- Change in vegetation greenness (derived from the Normalized Difference Vegetation Index [NDVI]); and
- Weedy invasive plants as a percent of total plant cover.

Each variable is scaled to a common unit; for example slight, moderate, or severe, and then weighted to reflect its relative importance with respect to other variables (in this particular study area). The data were integrated over a regional geographic setting using a GIS, which facilitated data display, development and exploration of data relationships, including manipulation and simulation testing. By combining the five data layers, landscapes having varying risks and combinations of risks for land degradation processes can be identified, aiding in targeting efficient land management strategies required.

While not used in their study, the authors suggest the following as potential indicators for evaluating the risk for desertification: soil salinization; albedo (surface reflectance) as an indicator of surface soil condition and/or erosion; erosion index other than albedo; depth to water table; change in Net Primary Production (NPP) as measured by the AVHRR NDVI over time; species richness/diversity: vegetation species composition data; change in human population; income per capita; land ownership; ratio of soil carbon to nitrogen; leaf area index; soil organic matter; litter cover; Bowen's Ratio; off-road vehicle use and road development.

Omar *et al.* (1998) assessed the extent of land degradation in an area of Kuwait using data in land-use patterns, soil characteristics and vegetation attributes. The soil chemical and physical properties were described and determined at various depths in representative profiles. The study proved that the USGS system of land classification was successful in mapping agricultural areas by aerial photography interpretation.

van Lynden and Mantel (2001) describe the use of GIS and remote sensing to make a comprehensive inventory of natural resources, degradation status and risk and an inventory of conservation measures being applied, using internationally accepted standardised methodologies. GIS and remote sensing have an increasingly important role for the integration and analysis of data on natural resources and socio-economic elements. In particular, they can be used for detection (direct or indirect), extrapolation and interpretation, area calculation, and monitoring. More specifically, GIS and/or remote sensing has been or could be used: to identify physiographic units; to serve as a common (physiographic) base map for assessments of different kinds of soils, degradation, and conservation; to overlay data layers for different map units; to make area calculations; to link spatial data with non-spatial but more detailed attribute data; to make geo-referenced information easily accessible to non-GIS users; to extrapolate results from smaller plots or areas to larger areas; to present data in map and other graphic format; to map (temporal and spatial changes in) land cover and land use; and to identify areas of degradation.

The authors discuss the assessment of human-induced soil degradation in South and South-East Asia. A physiographic map (with a scale of 1:5,000,000) was prepared for Asia following the SOTER criteria on the basis of topographic maps of varying quality and some visual interpretation of satellite images. The map was used as a template for mapping the status of soil degradation using the ASSOD method. For each polygon of the base map, data were collected on the relative extent of degradation, its impact on productivity, the rate of degradation, and its causative factors.

Information for individual polygons was collected through matrix forms on:

- Major land use types (extent, trends);
- Degradation (like in ASSOD, but differentiated per land use type);
- Soil and water conservation (type, extent, effectiveness and trend, period of implementation);
- Productivity (trend, role of SWC, approximate input and output figures).

The attribute data were stored in a database, which is linked to the polygons of the physiographic map. Thematic maps on specific soil and water conservation aspects could thus be prepared. The WOCAT mapping exercise was accompanied by a more comprehensive but non-geo-referenced inventory of SWC technologies and approaches. Through a reference field in the map database, access to many more details of a given technology is thus possible.

Agnew and Warren (1996) developed a framework for dryland management for arid environments named 'EPOCHS' after the sequence of analytical steps: Environmental conditions, Problem definition, Occurrence (intensity), Cause, Help/Solution.

Abdelgalil and Cohen (2001) developed an agricultural policy model of the trade-off between agricultural growth and land degradation that shares common features with the computable general equilibrium (CGE) models. The model is used to address the question: which among the four policies of price incentives, property rights, poverty reduction, and human capital are most effective?

The authors developed a model consisting of 10 equations and applied it in Sudan. Eight equations describe the activities and various outcomes for three land types. The ninth equation outlines the degradation effects of land use, and the tenth equation refers to the government budget as affected by policies that it pursues for the agricultural sector as a whole.

The policy model applied incorporates the joint appraisal of economic incentives, property rights, poverty pressure, and the role of modern farming knowledge in the determination of growth and sustainability of agriculture. The model gives due emphasis to relative prices in influencing the allocation of resources and shares common features with CGE models.

IV. DEGRADATION ASSESSMENT AND ITS TRENDS IN THE ESCWA REGION

A. BACKGROUND

The land resources in the ESCWA region hold fragile dryland ecosystems that are the source of livelihood to a relatively large population in the region. Despite being fragile ecosystems land resources play a key role in the sustenance of the region's population. Yet, while attempting to determine the state of land resources, it has been recognized by parties to the United Nations Convention to Combat Desertification (UNCCD), that not enough is known about the nature, severity and extent of land degradation and about its causes and the responses from populations to such states of land degradation. Efforts to characterize and quantify the type, intensity and extent of land degradation processes at multiple scales, in the global context in general, and in the drylands of the ESCWA region in particular have provided valuable data and information. Yet, many questions, particularly related to the linkage of the state of degradation to its causes (i.e. driving forces and pressures) and to the impacts of land degradation on livelihoods, remain unanswered. There is an obvious and urgent need to incorporate what is known from past and present assessment methods into integrative paradigms, in order to connect land degradation processes and states to their root causes and to answer pressing questions that decision and policy makers in the region require to answer to formulate effective policy.

The design of a methodological framework for the assessment of land degradation in the ESCWA region, that addresses the concerns stated above, and yet provides users with a reliable, flexible, quantitative and reproducible assessment framework of methods and procedures, is the main objective of the efforts reposted in this document. The methods and procedures in the framework are to be validated further through assessment activities to be undertaken by ESCWA countries in their dryland jurisdictions, in order to make them widely available, while demonstrating their applicability and building local capacities. The land degradation methodological framework proposed here, while considering the tested elements of past and present methodologies, it should integrate the biophysical components of land degradation to the social, economic, cultural and policy contexts where degradation occurs so that the identification of causes and responses to degradation as well as its impacts on livelihoods of rural populations can be known.

It must be noted that significant efforts are already underway to develop a solid methodological framework for land degradation assessment in the drylands of the world, lead by the global LADA project (FAO, 2004; http://www.fao.org/ag/agl/agll/lada/default.stm), and that this methodological proposal shows a significant degree of overlap in approach and methods to the proposed LADA framework. This fact is in line with the desirability to count with harmonized methodologies to make results of assessments comparable and transferable. It should also be noted that the consultant authoring this report has contributed significantly to the LADA methodological process and efforts since its formulation and inception.

For the purposes of describing the methodological framework in a consistent way, it is necessary first to clarify definitions, concepts and terms, which are used and involved in the component methods of the framework. For the definitions of **land, drylands**, **land degradation**, and **desertification** the LADA Workshop (FAO, 2002) recommended adoption of the UNCCD (Article 1) terminology and definitions as a basis, whilst ensuring harmonization with definitions in use elsewhere, such as those employed in the FAO Global Agro-Ecological Zones framework (GAEZ). Specifically, the UNCCD definition of land is effectively equivalent to that employed since 1976 by FAO. References in LADA documentation to "land degradation in drylands" are equivalent to the UNCCD definition of "desertification". Land can be defined as (FAO, 1995):

> *"...a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the near-surface climate the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal*

populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)."

This definition of land emphasizes the functional and systemic relationships among its attributes. The knowledge of such relationships allows for the identification and delineation of units of land whose understanding is essential in the analysis of the dynamic processes that intervene in land degradation. Such areas of land are actually delineated on the basis of both a recognizable pattern of attributes and functional relationships among these attributes. The identification, characterization and mapping of the different areas of "land" seem pertinent as the starting point for any attempts at assessing its state of degradation.

Drylands cover most of the areas of the countries in the ESCWA region (Figure 2). Drylands comprise areas having a ratio of P/PET < 0.65, where P is precipitation and PET is potential evapo-transpiration. A further breakdown of this range yields definitions of **"hyper-arid"** (P/PET< 0.05) **"arid"** (0.05<P/PET< 0.20) **"semi-arid"** (0.20<P/PET< 0.50), and **"dry sub-humid"** (0.50<P/PET< 0.65). "**Susceptible drylands**" are considered the arid, semiarid, and dry sub-humid regions of the earth (van Lynden and Kuhlmann, 2002).

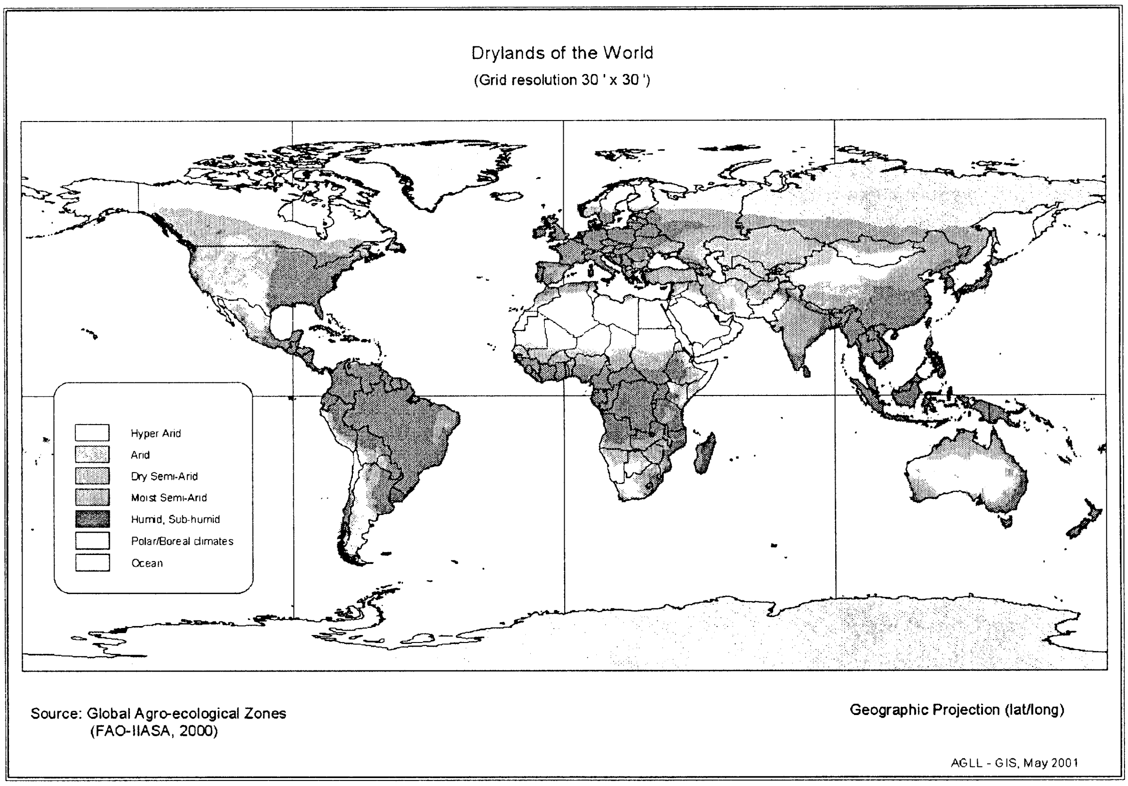


Figure 2: Drylands of the world including nearly the entire ESCWA region as drylands.

Land degradation is a complex set of processes of impoverishment of terrestrial ecosystems under the impact of human activities. Land degradation can be understood as the reduction or loss of biological or economic productivity and complexity of the land resulting from human activities, mainly from the mismatch between land quality and the intensity of activities part of the actual land use (UNCCD, 1994). The manifestations of land degradation can be measured in terms of:

- Reduced productivity of desired plants
- Undesirable alterations in the biomass and the diversity of micro and macro flora and fauna (soil biodiversity)
- Accelerated soil physical, chemical and biological deterioration

- Undesirable alterations in ecosystem services
- Increased hazards for human occupancy
- Land degradation in arid, semi-arid and dry sub-humid lands (drylands) resulting from various factors including climatic variations and human activities leads eventually to desertification.

Desertification has been defined in the United Nations Convention to Combat Desertification (UNCCD, 1994) as land degradation occurring in arid, semiarid and dry sub-humid areas caused by a combination of climatic factors and human activities. Hence, only land degradation occurring in drylands as defined above is considered to be part of a desertification process.

Assessment involves judgement, evaluation or comparison. Assessment makes necessary the definition of a baseline or reference for the evaluation or comparison. Land degradation is the subject of perception. For whom a land is degraded, with what intensity and to what extent will depend on the perception or the baseline of reference by different people. Differences in perceptions of land degradation may occur between scientists, land users, policy makers, government agencies, and even between scientists of different disciplines. These differences in perception, particularly those from the land users themselves, need to be accounted for into a holistic view. A baseline must be established before the assessment. The establishment of a baseline has practical implications since the reference level could change from place to place depending on the intensity of human interventions in ecosystems. The baseline level could range from "pristine ecosystems" to an extreme level of intervention and its associated state of degradation. For practical purposes, Bunning and Jimenez (2003) report that the characteristics (i.e. indicator variables) of an undisturbed/ healthy soil in a similar ecosystem as that of the site of the assessment, can serve as an initial reference point with acceptable allowances for shifts in the status of such indicators (usually less "healthy") due to disturbance created by historical cropping and pasture regimes imposed on the initial undisturbed/ healthy soil.

The intensity or severity of land degradation and its spatial extent are important pieces of information for the formulation of action plans and policies to reverse it and if possible to prevent it. Therefore it is important to define the terms "extent" and "severity".

Extent indicates distribution in both, spatial and temporal dimensions of the different degrees of intensity of the process. Typically the mapping of the spatial dimension (geographical distribution) is the foundation for the monitoring of temporal variations.

Severity refers to the intensity of the process or state of degradation and suggests the definition of a scale of intensity, whether categorical or numerical, continuous or discrete.

A central objective of the methodological framework is to map out a set of methodological pathways for the assessment or evaluation, and the necessary tools to carry out the assessment and quantification of the extent and severity of land degradation in any given area. However, it is fundamental to consider that in order to formulate, enact and implement effective policy measures to combat land degradation, its root causes need to be known and well understood so as to suggest remediation actions associated to the causes, rather than attacking and attempting to reverse its symptoms and its impacts.

Existing assessment methods of land degradation including the GLASOD (UNEP/ISRIC, 1991); the Desertification Atlas (UNEP, 1992); and the more detailed ASSOD study (UNEP/ISRIC, 1997) generally were bio-physical in nature and only limited to the identification of the primary process of degradation (e.g. water or wind erosion) and a few causative land use factors (e.g. overgrazing), but with limited reference to procedures for investigating and accounting, in a systematic way, for the root causes of the land degradation processes.

Causes can be understood as the direct agents that promote negative change resulting in a given state of land degradation. Causes are the direct **pressures** exerted on land resources under which the onset of degradation or deterioration processes occurs. These pressures are, in turn, caused themselves by **driving forces** of a variety of origins (i.e. economic, social, political, etc.), which can be understood as indirect causes of land degradation. The drives for the satisfaction of basic human needs, first, and then for the pursuit of other non-essential satisfactions of human populations are the **driving forces** that translate into **pressures** that are exerted on land resources.

The land degradation assessment methodological framework for the ESCWA region should aim at assessing, at the same time with the states of degradation, the causes and impacts of land degradation and possible responses. Therefore these causes need to be characterized and evaluated. Establishing causality usually demands a deep understanding of the dynamics of the systems (economic, social and cultural and their bearing on the biophysical), and above all of their interactions as they express themselves in the particular geographical location. The identification of causality through the dynamics of a natural or managed system necessitates of mapping the **networks of causal chains** from states of degradation to the pressures exerted on the resource and on to the driving forces causing the pressures. This can be achieved via mapping the linkages between direct indicators of **the state** of degradation to the direct **pressure** indicators and up to those of **driving forces** (indirect indicators). So, a **causal chain** is established. Several causal chains may be linked or rely on similar indicators creating a network. Thus, the **networks of causal chains** connect the state of degradation to its causes.

The identification of the direct causative factors or pressures on the land, in some cases may be relatively straightforward. In others, due to the working scale or to the resolution of the data, or where there are no evident **indicators**, it may involve more exhaustive investigation. Among the straightforward identification of direct causative factors, for instance, inappropriate or over-intensive land use and land management practices are often the most important factor of land degradation in drylands. Livestock grazing in high densities and with static grazing patterns may alter floristic composition, reduce biodiversity, increase soil compaction and in extreme cases eliminate vegetation cover altogether (White *et al*, 2002). Fire, whether natural or induced may affect vegetation density and diversity. The encroachment of urban centres and human settlements permanently inhibit the natural functions of drylands, while at the same time increasing the pressure on the surroundings for increased services such as water, sanitation and waste disposal. The creation of impervious surfaces by paving and compaction of the soil, changes the drainage pattern inhibits groundwater recharge and leads to increased runoff. All of the above are examples of **indicator variables** that can be very useful in the identification of causes and states of land degradation.

Impacts refer to changes on the different aspects of people's livelihoods imposed by the state of land degradation and its causes. These impacts manifest themselves on the multiple functions of the land, which include providing food and fibres and a livelihood for people, serving as a buffer between the atmosphere and underground water resources, providing mineral and organic resources, storing carbon and preserving biological diversity, providing support for infrastructure, opportunities for tourism and being a repository of archaeological values. This suggests that degradation processes may affect multiple components of a system, from the natural, financial or economic, social, cultural and human capitals. The changes imposed by land degradation on all these aspects, which are characterized here as impacts, must be significant and measurable or appreciable.

Responses are understood as the direct or indirect actions taken by land users and managers to the impacts on their livelihood caused by the state of land degradation, the pressures on the land causing such state, and the driving forces causing such pressures. Such responses may manifest themselves as possible **remediation actions.** The experience of land users themselves, who run informal "experiments" with nature through their responses in their particular lands, accrue knowledge and experience about remediation actions.

Indicators are variables, parameters (even in the statistical sense), or measures, which provide evidence of a condition, change of quality, or change in state of something valued (Dumanski and Pieri, 1996). Land quality indicators, for instance, include statistics that report on the condition and quality of the land resource itself. They may also reflect the cause-effect relationships that may result in changes in quality, and on the responses to these changes by society. An **index** is the result of the aggregation of several indicators according to some mathematical expression or formula. FAO (2003) provides a comprehensive overview of possible indicators to be used in an assessment of dryland degradation. Several of these may prove quite useful for initial determination of specific degradation status, causes and impacts. Indicators may help in the assessment by detecting and identifying the types of degradation and by assessing their severity determining and analyzing the cause-effect relationships involved, with a view to identifying trends and taking remedial action.

1. Types of land degradation

According to the nature of the processes involved, the types of land degradation can be: physical, chemical and biological (Figure 3).

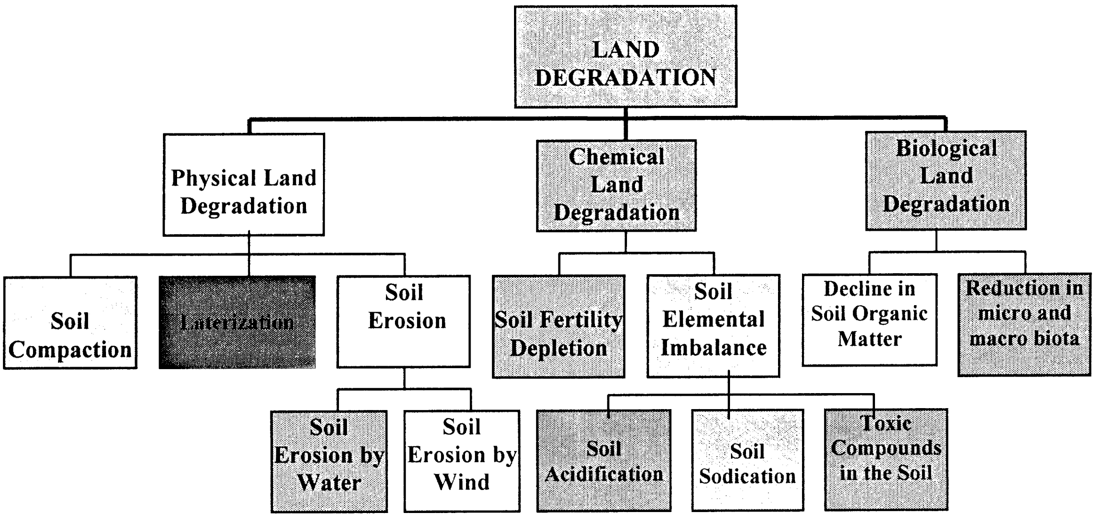


Figure 39. Networks of social driving forces, pressures and states in

Figure 3. Types of land degradation processes

The land degradation assessment methodology for the ESCWA region should aim at providing analytical pathways to achieve the assessment of the three types of degradation, namely, physical, chemical and biological and the manifestations of their degradation processes (i.e. compaction, erosion, accumulation of toxic compounds, etc.) in the areas of concern. From the outset, it is clear that some types of degradation and processes are more prevalent in the lands of the ESCWA region (e.g. soil erosion by water and wind, salinization or sodication, reduction of macro and micro biota, soil fertility depletion and decline of soil organic matter, accumulation of toxic compounds, soil compaction, etc.). However a methodological framework for ESCWA should provide assessment tools and analytical pathways for all types and processes of land degradation.

B. ASSUMPTIONS AND FRAMEWORK PRINCIPLES

The methodological framework for land degradation assessment in the ESCWA region rests on a set of core assumptions that underpin the approach to the assessment. The description of the characteristics of the approach makes evident such assumptions, both of theoretical and practical nature. These are described next.

1. About the causes of land degradation its impacts and the formulation of policies.

The methodological framework places the states of land degradation in the ESCWA lands as the central focus of the assessment, while recognizing that the elucidation of its causes (direct and indirect) are of paramount importance to the formulation of policies for its control and reversal. It assumes that the impacts that the current state of degradation has on dryland ecosystem services and how, in turn, these impact too the livelihoods of people and their five capitals (natural, financial, social, human and physical) are equally important for policy formulation.

2. The approach to the methodological framework

The framework assumes that the appropriate approach to follow in the assessment of land degradation for the ESCWA region is the Driving Forces-Pressures-States-Impacts-Response (DPSIR) approach. The DPSIR approach allows for the understanding of the direct and indirect causes of the present states of land degradation, their impacts and the responses that people have generated, to counter the adversity caused by land degradation and the decrease in ecosystem services. The DPSIR approach has been undertaken for the global assessment of dryland degradation at multiple scales by the LADA project (FAO, 2004), and it is a major component of the Ecosystems and Human Well-Being study (Millennium Ecosystem Assessment, 2003). Thus, the DPSIR approach allows for identification of causative factors and for the mapping of the linkages to the states (intensity) and types of degradation, all of which should be reflected in a mapping legend for spatial display purposes. Moreover, the DPSIR approach is the mechanism used by for the framework proposed here, for the integration of the biophysical to the social, economic, cultural and policy factors of land degradation, and it is applied in the context of the interplay and trade-offs between the five capitals (natural, social, financial, physical and human). The diagram in Figure 4 illustrates the relationships between the elements of the DPSIR approach.

3. Multiple scales for the assessment

The framework also recognizes that the principles of the DPSIR approach operate at multiple scales and therefore it assumes that assessments at scales ranging from regional to local and from local to regional can be harmonized. Different manifestations of causative factors (driving forces and pressures) at different scales can be elucidated through their indicators at each scale, and that the evidence of the states of degradation and its impacts and responses will also be indicated by different variables at each scale.

Therefore, the DPSIR approach can be adopted at multiple scales and the impacts on livelihoods can be analyzed through the effects on the five livelihood capitals, namely: natural, physical, financial, social and human. The relationships between the DPSIR approach and the impacts on the five capitals at different scales are illustrated in Figure 5.

Land degradation assessments at multiple scales will be needed in the ESCWA region and they should be implemented. Assessments results at a one given scale should not contradict results at another scale but, rather, it should be possible to aggregate and disaggregate, upscale and downscale assessment results at multiple scales harmoniously. At each scale of the assessment a set of indicators (IS), applicable to that particular scale should be clearly identified and stated. Together with the indicator set at each scale, the applicable set of analytical procedures and tools (M) should be identified and declared (i.e. land cover changes as indicator of degradation detected by remote sensing may be quite useful at regional, national and watershed scales, but not necessarily so at the local level or at the farmer's plot. So for a given scale there is an appropriate set of indicators (IS), methods of analysis (M) and models or tools (Mod) that is applicable and most suitable for the assessment. This is illustrated in Figure 6, below.

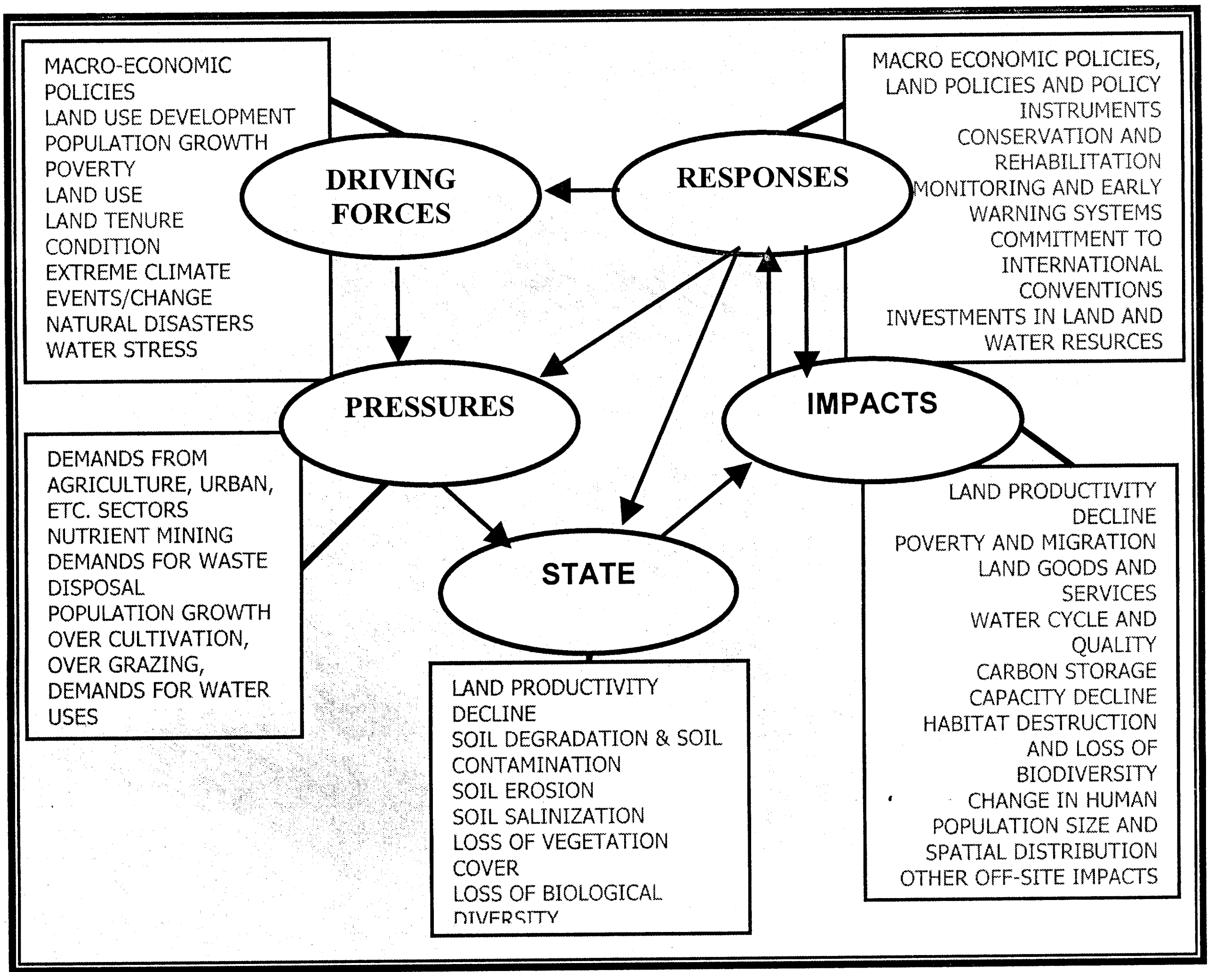


Figure 4. The Driving Forces-State-Impact-Response (DPSIR) Approach as applied to land degradation (after FAO, 2001 and Ponce-Hernandez and Koohafkan, 2004)

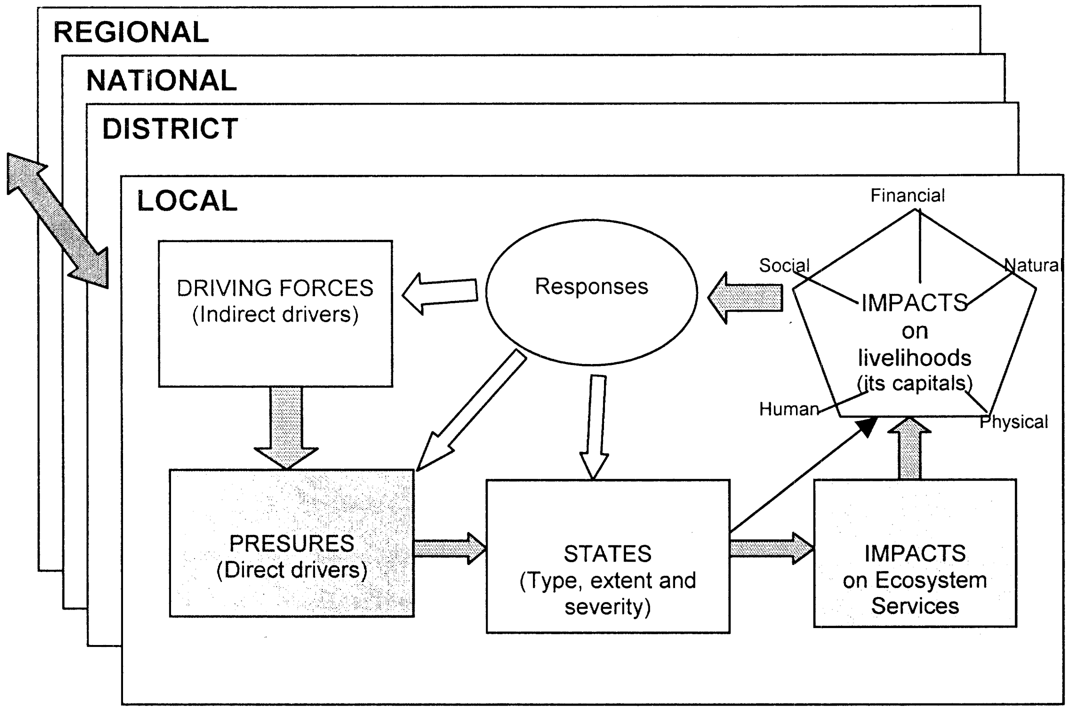


Figure 5. The DPSIR and the five capitals at multiple scales, as part of the conceptual framework for the ESCWA region.

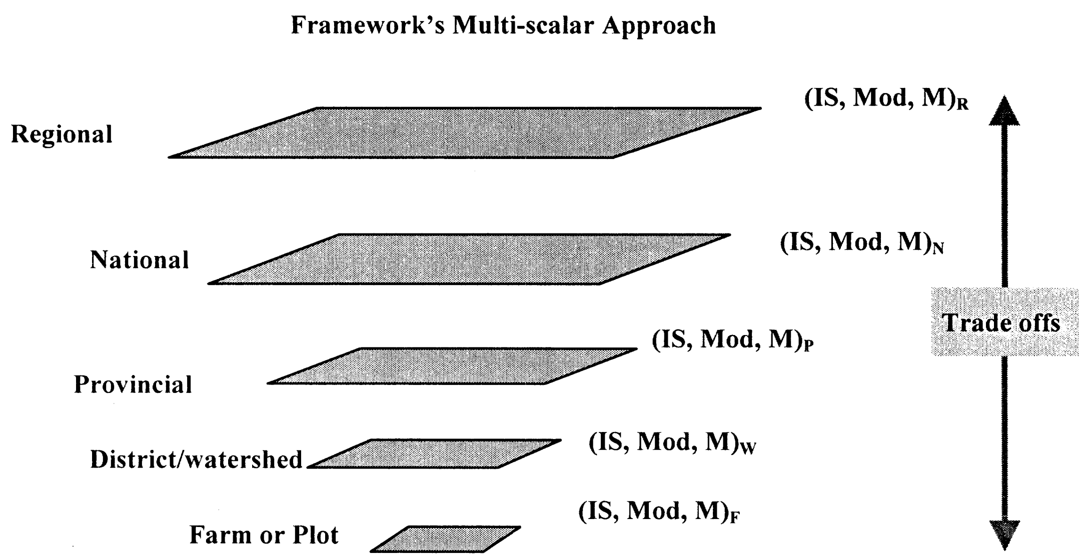


Figure 6. Framework's multi-scalar approach. Note: At each scale there is a suitable set of indicators (IS), models (Mod) and tools (M) that are applicable, and trade offs in: data resolution, accuracy, complexity of analysis, time and costs.

Similar reasoning applies to all methods and quantification procedures used and their modelling tools. Simulation of sediment and nutrient transport may not be very relevant within a field, and modelling tools may not be applicable at the national scale. The trade-offs between accuracy of results and data resolution and completeness at the scale of assessment should be recognized and stated in the assessment report. The degree of accuracy of results should be fixed and standardized for all assessments as to allow for comparisons anywhere in the globe. The target accuracy of results should be the standard fixed for all assessments at the given scale, then as a function of the degree of completeness of the databases initially available for the assessment and the resolution of the data, the investment in assessment efforts and resources should be calculated in order to achieve the target accuracy. These issues and the issue of data completion should be clear to the assessment team and stated in the assessment report. An important consideration in this respect is that the link between local and national levels needs to be maintained. Causal factors of land degradation identified locally should also be extrapolated and taken into account nationally.

4. *Framework Principles*

The fundamental principles on which the framework is predicated need to be stated. The principles underpin the structure of the framework and its function and application. Such principles are deemed applicable at all scales of assessment and under any circumstances of data availability and completeness, available technology and social, economic, cultural and environmental setting and contexts. In this sense, the framework principles are its structure. They are unchangeable and are reflected in the methods and procedures that are component of the framework. The description of these principles follows.

(a) Complexity vs. accuracy and reproducibility

Land degradation is a complex process and its causes and impacts are varied and multiple. To provide with reproducible and comparable assessment results from different districts and different countries, the selection of the methods and procedures to be employed are to be commensurate with the grain and completeness of the data available, the technology, tools and technical knowledge of the assessor. These should be stated as part of the assessment outcomes. Accurate, reproducible and therefore reliable estimates often demand complex methods, yet in order to be accessible methods are required to be simple. This apparent contradiction calls for compromises to be made between simplicity and accessibility of methods and accuracy of results. Powerful (therefore maybe complex) analytical tools may be used when possible. On the other hand, over-generalization, and subjectivity are to be avoided since they often run against reproducibility, accuracy, consistency and therefore scientific soundness. According to data quality, technology and technical knowledge the tools from the framework should be selected and they should be reported as part of the assessment results. Ultimately, the methodology is to provide information for decision- and policy-makers. This should be born in mind by national teams executing the assessment.

(b) Flexibility

The methodological framework should be flexible, since the problem of land degradation in drylands is too complex for a universal, standard assessment methodology. Flexibility and compatibility of procedures and methods with scale and data availability and resolution is paramount to the approach. The flexibility of the framework rests on its being a collection of methods and pathways to indicate how these methods are sequentially related in terms of data and information flows, inputs/outputs and in synchrony. The framework should be considered as a **"toolbox"** of methods and analytical tools, and procedures on how to use them. Users implementing the framework should take from it what is needed in their particular assessment circumstances and adapt it. The flexibility allows also for adaptations to the particular circumstances of the assessment in terms of technical knowledge of the assessing team, data quality and completeness, idiosyncratic considerations and cultural backgrounds. Additions to the toolbox and modifications are possible as long as they are stated and a common reporting language and legend are used.

(c) *Systems approach*

The methodological framework uses a systems approach so that the structure and dynamics of the land degradation processes are understood. The need to identify causes and responses within the biophysical, social, economic and cultural contexts and at multiple scales and their interconnections makes it imperative the adoption of a systems approach. The systems approach focuses on the interactions of the multiple elements of the process and therefore enables the mapping of the causal chains to states and impacts of land degradation.

(d) *Participatory, approximative, adaptive and recursive*

The methodological framework of the kind proposed for the ESCWA region should be participatory, attempting to build on the integration of knowledge and experience from multiple stakeholders, notably farmers, land users and practitioners in the field, in as much as from natural, economics and social scientists, decision- and policy-makers. This will enrich the methodological framework by incorporating their multiple perspectives. The development of the methodological framework, given its participatory nature, will require successive approximations through an iterative process that incorporates new knowledge and insights at each stage, adapting to new circumstances and situations and therefore improving the methods over time and from practical results.

(e) *Indicative and Modular*

The framework is indicative in the sense of using **"indicators"** for quantification purposes. In recognition of the low likelihood or feasibility of direct measurement of land degradation processes, or of the lack of available data, it will be necessary to use "indicator" variables to determine by "proxy" the nature and intensity of the status of land degradation. Indicators are derived even from interpreting observations or commentary from farmers, land users and other stakeholders related to the status of degradation of their lands. In this sense the framework's approach is indicative. The flexibility and the approximative nature of the methodological framework make it imperative to divide the totality of it into its logical parts in terms of modules. A **modular** methodological framework should be seen as a **"toolbox"** from which the appropriate methods, procedures and modelling tools should be drawn for the assessment from each module, depending on the aspect of the assessment being implemented.

(f) *Integrative and based on sound science*

Views of land degradation in past assessment efforts have been largely resource-centred or discipline-centred. This has hampered the full understanding of processes and causes of land degradation, and of the societal responses to it. Such understanding is essential for the formulation of useful policies for tackling land degradation. Integration through a systems approach should be adopted for the different steps in the analysis. The methods in the framework should be based on current science and should make use of modern technology. The application of the framework should yield a set of results that are based on methods and procedures, which, while as simple and accessible as possible, have sufficient rigour to be transferable, reproducible and consistent, allowing for regional comparisons and compatibility of results at multiple scales.

(g) *Harmonized and subject to quality control*

The ESCWA methodological framework, being an international initiative, should promote methodologies and data and information bases that are compatible across countries and ecosystems. The framework should develop common concepts for data collection and analysis that enable the exchange of results and permit up- and downscaling among local, national, regional and global scales (e.g. the global LADA project). Even when harmonized methodologies are agreed upon and are applied, quality control is still necessary. Implementation of these methods depends on the expertise applied, the political will expressed and the financial resources made available. A mechanism is to be put in place that allows fixing standards of accuracy of results and assessing the quality of the data produced by land degradation assessment activities at different scales.

(h) *Results-driven and practical*

The ESCWA methodological framework for the assessment is results-driven. The application of the framework will seek to provide concrete practical results of assessments in terms of data and information that stakeholders need for decision-making to respond to land degradation. In order to implement a results-driven approach, a problem-solving strategy of "working backwards" from the "deliverables" or "desired answers to questions", to the "givens" or data available. Both, the questions for which answers are sought, and the available data need to be defined absolutely clearly by stakeholders in terms of the data and information required for decision-making. The results based approach would "walk backwards form final results to the givens", filling in the steps required to convert the "givens" to the end result or "deliverables", as illustrated in Figure 7. This requires of three fundamental conditions: 1. A clear definition of the data and information required as results from the assessment, 2. The minimum data sets to attain meaningful practical results, and 3. The available data and the state of the databases to attain the target results that decision-makers require for policy formulation.

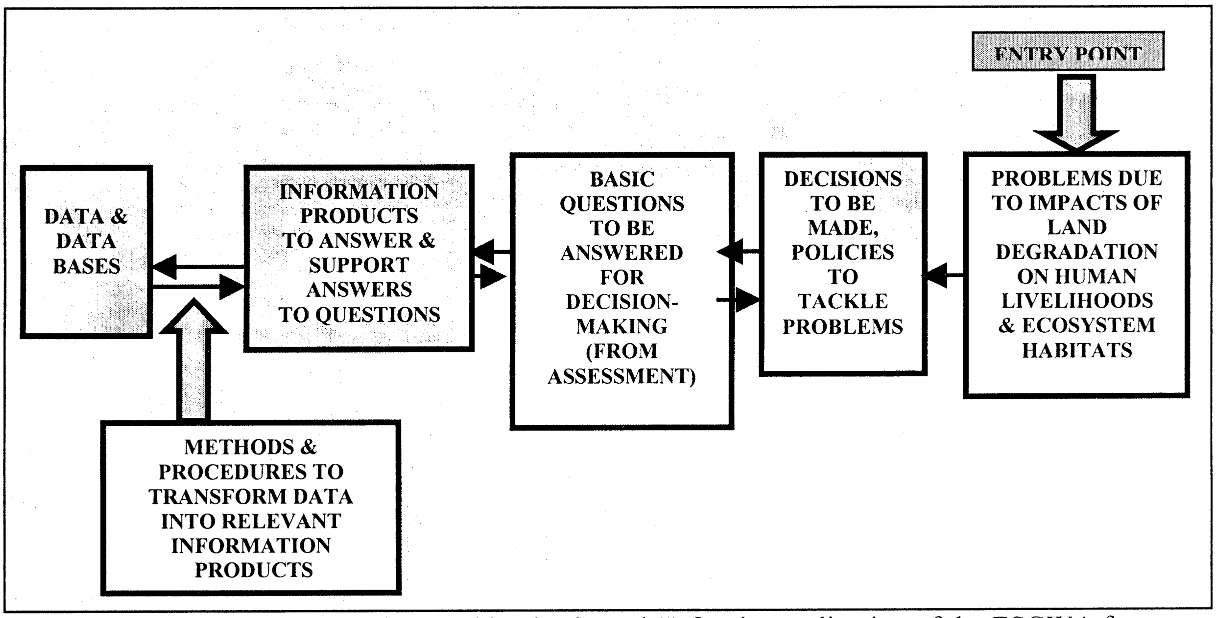


Figure 7. Results-driven approach ("working backwards") for the application of the ESCWA framework

5. *Conceptual understanding of the dynamics of the land degradation process and the five capitals*

The framework sets out to recognize two major components that are fundamental in the land degradation process, namely: the land resources and the human populations living on and from them. These major components are, in effect, the two major sources of data and the two major kinds of databases: the biophysical, on the one hand, and the socio-economic and demographic on the other. The five capitals (Social, Financial, Natural, Human and Physical) are contained within them. The dynamic relationships between these two components in terms of "Driving Forces-Pressure-State-Impact-Response" (DPSIR) describe the flows of causality in the land degradation processes and the responses to them.

Populations access the resource base, modify it and obtain products and services, which provide sustenance by virtue of the modifications of the natural environment. Human population groups can also be characterized in terms of the structure and population dynamics. These are described by demographics

(Figure 9). Human populations have created constructs: government bodies with their own structure, policies and regulatory frameworks, social and cultural entities, institutions and structures of power. Human groups have also developed the economic systems to trade in goods and services, many of which are derived from the access, occupation and use of the land. So the entities created by human groups are: government and its agencies, its policies and regulations, social and cultural structures, institutions and structures of power, and economic systems.

The land resource consists of the biophysical environment, which is understood in terms of habitats and ecosystems, whose boundaries are, in fact, operational definitions. Ecosystems can be characterized in terms of their structure (organization) and functions (e.g. hydrological and nutrient cycles, plant growth, etc.), as illustrated in Figure 8.

The human capital, accessing, using and managing the natural capital through an initial physical capital, and supported by the financial and social capitals, manages to produce more physical capital (goods and services), all of which, in turn represent more financial capital. Financial capital is accrued and the reminder apportioned between the physical (infrastructure) and human (food security, health, education) capitals. These flows of capitals appear to occur in a kind of cyclical path where the dynamic component of the flow occurs in terms of the financial capital. However, at the core of the flows is the natural capital in terms of the generation of "new" physical capital (goods, services and infrastructure) and financial capital.

The manner and intensity in which human activities through land use and land management cause the degradation of the land resource base can be in terms of how the intensity on land use and the appropriateness of management fit the equilibrium of natural (hydrological, energy and nutrient) cycles and the structure and function of landforms and their components (topography, soils and organisms below and above ground). This is illustrated in Figure 8. So the relationships between human activities and land resources flow from the relationships illustrated in Figure 9 to those illustrated in Figure 8. A detailed mapping of all relationships between human activities and their effects in each of the components of the environment and particularly on those of land resources is practically impossible. However, a detailed mapping as possible of the multiple driving forces manifesting themselves into a wide variety of pressures on the land, causing multiple manifestations of the states of land degradation, impacts on people's livelihoods and responses from them can be attempted. This is necessary so as to achieve an understanding and to picture as graphically as possible the nature of the DPSIR and the processes affected and their causes. A flow chart (Figure 10) as complete as possible was attempted by Ponce-Hernandez (2002), working in the methodological design for the land degradation in drylands (LADA) project. The diagram (Figure 10) is pertinent in the ESCWA Region, whose resources are dryland ecosystems. Moreover, in spite of the complexity of the diagram, it offers a comprehensive list of components of the DPSIR connections that need to be address in terms of methods and procedures by any methodological framework to be implemented in the region. The full DPSIR diagram in Figure 10 can be seen as much more detailed mapping emerging from the combination of the diagrams in Figures 8 and 9.

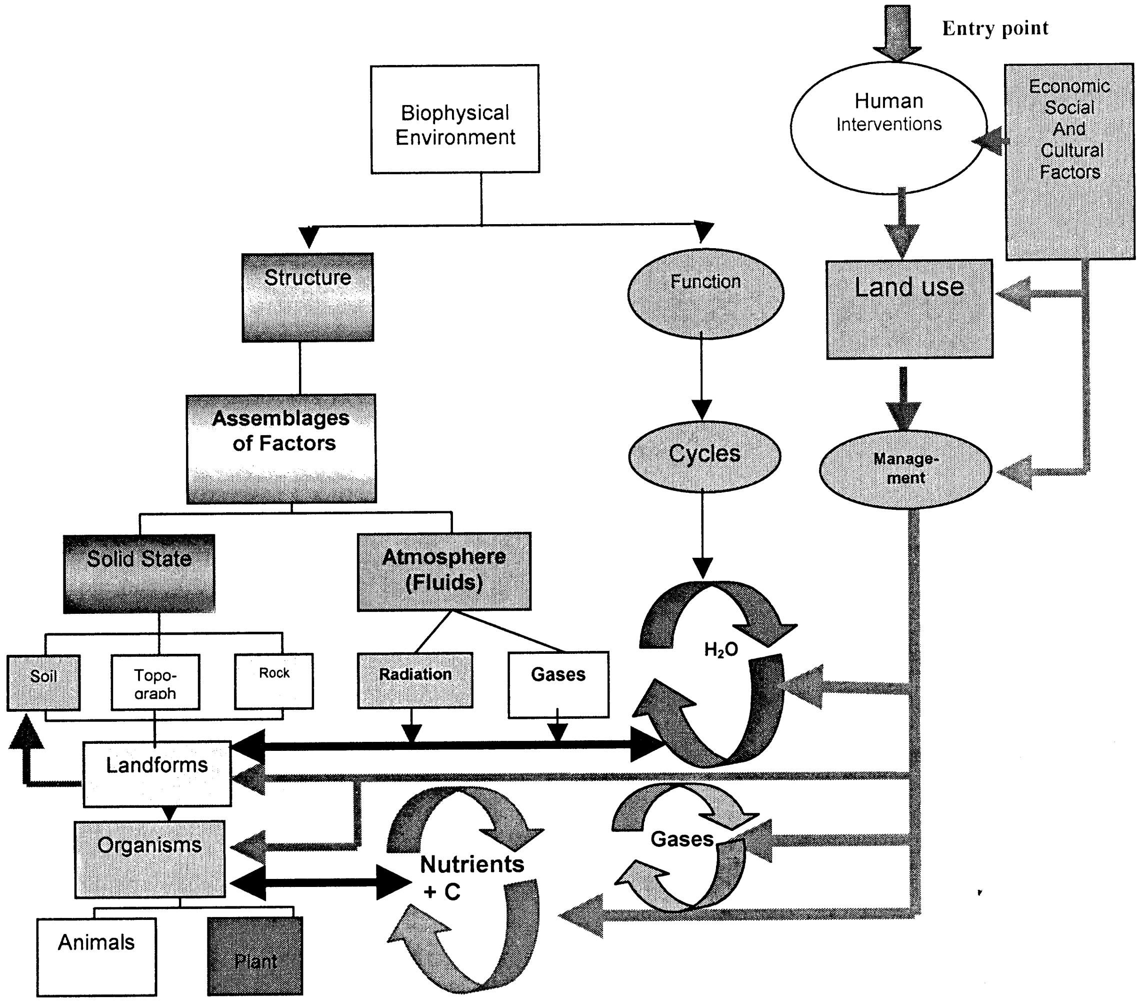


Figure 8. The human (social, economic and cultural) elements that effect land degradation and their dynamic relationships

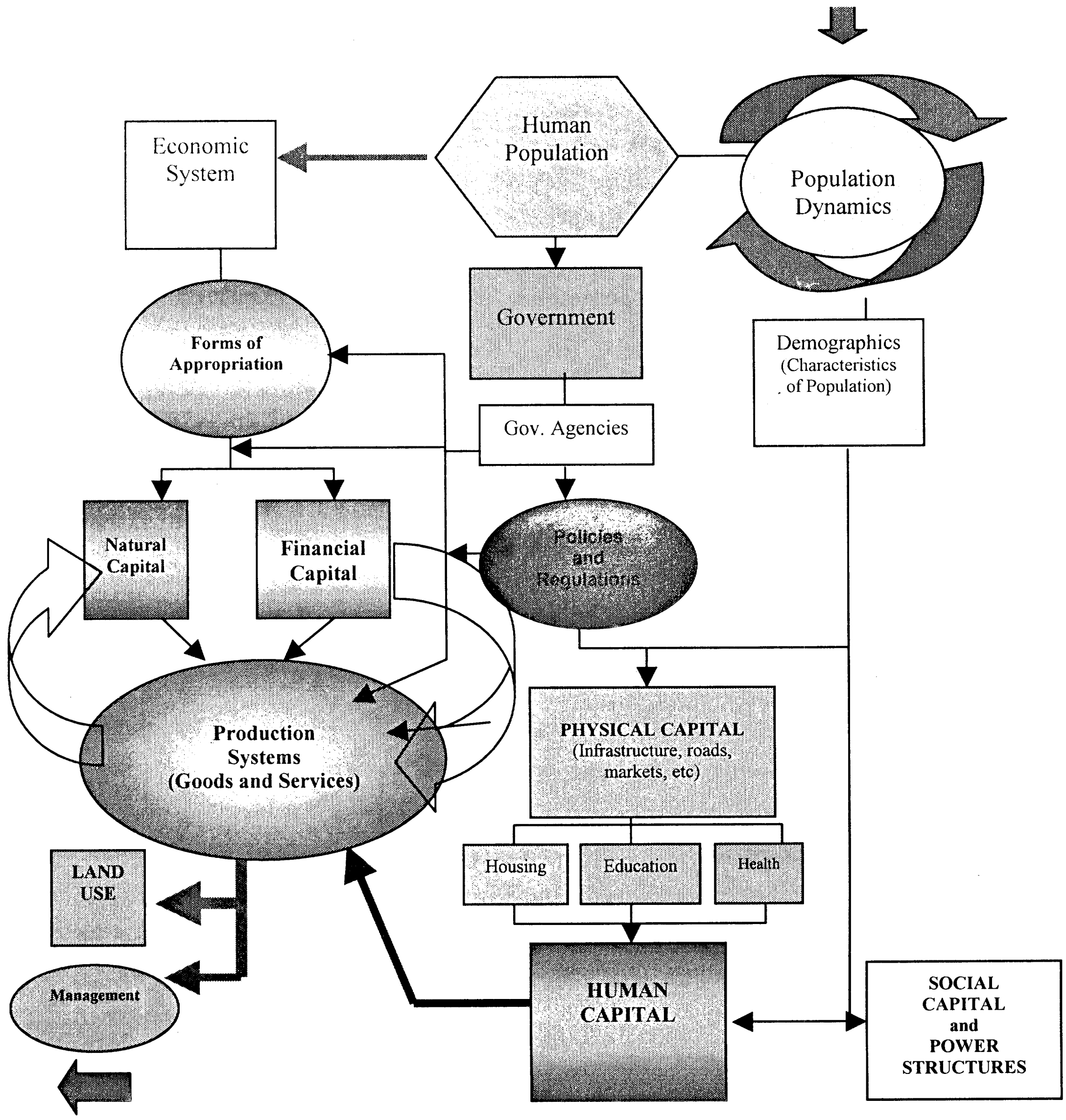


Figure 9. The Land Resource component with all its elements and cycles and their dynamic relationships as they are affected by the human component through land use and management (red and blue arrows) causing changes in cycles, landforms and related organisms (plants and animals)

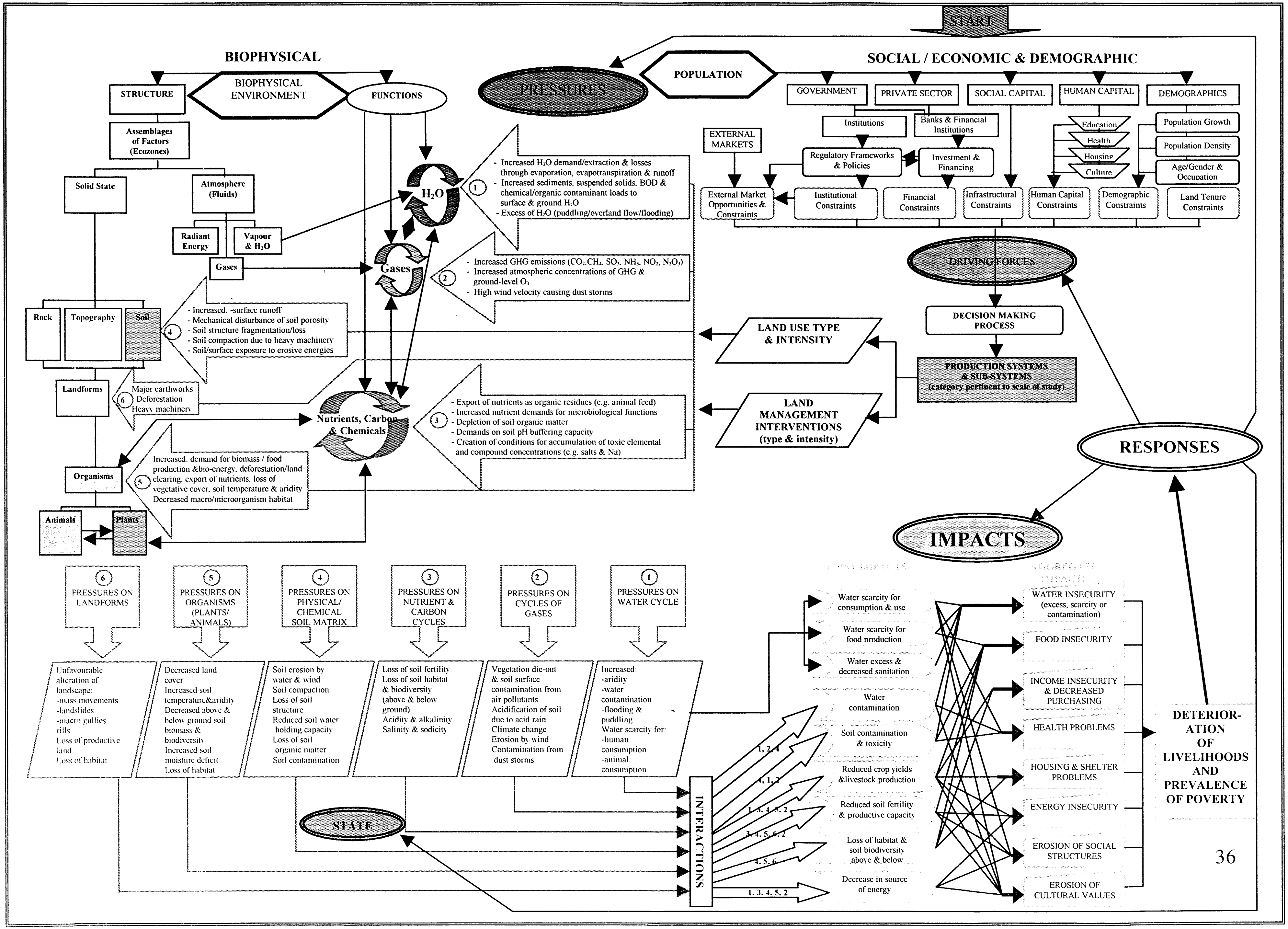


Figure 10. The connections between driving forces, pressures, state, impacts and responses (Ponce, 2002).

C. Description of the Methodological Framework

1. Framework Structure

The ESCWA methodological framework stemming from the LADA framework is underpinned by an integrative modular systems approach. The base entity for the application of the methodological framework is the **country.** It is envisaged that sub-national assessments (i.e. provincial/regional, district/watershed or local) would contribute to put together the national picture of the state of degradation. The sub-national assessments, whether at the Provincial or Major Basin level, could be built from assessments at the District or Watershed levels. These, in turn, will be built form the local (village or farm groups) assessment levels, which based on adequate and statistically-sound sampling schemes can be the basis for "up-scaling" or "downscaling" to any regional or even global levels. Procedures for achieving downscaling and up scaling are also part of the framework. In this fashion the harmonization principle of the framework is achieved.

2. The Framework Modular Structure

The flexibility of the methodological framework makes it imperative that its totality is divided into its logical parts in terms of modules. Modular methodological development facilitates focus, detail in methods and ultimately usefulness. Developing by modules and integrating these later will guarantee attention to detail for each kind of land degradation and refinement in the application of procedures and techniques.

In the land degradation methodological framework, methods, procedures and analytical tools are all compartmentalized into "modules", which are oriented to achieving major tasks. This approach should bring enough flexibility to fit the current availability of data in existent databases as to accommodate for the particular circumstances of the country, or country region, province, major basin, district, watershed or village where the framework is applied. Given the multi-scalar nature of possible assessments, the variety of the land degradation processes to assess, and the types of land degradation to report on, it is considered that the modular approach to the framework is what best suits the variety of circumstances of assessments.

The modules in the framework can be seen as compartments of a "toolbox" containing methods, procedures, techniques and models that are relevant to the type of degradation process being assessed and the scale of the assessment. The assessment team, assisted by decision support systems would take from the "toolbox" the methods, procedures, models and analytical tools required to achieve a particular task depending on the assessment scale (e.g. land cover analysis module via remote sensing may be relevant and very useful at the regional, district/ watershed scale, while livelihood analysis module, field indicators module and modelling nutrient losses modules may be relevant at a community or local scale). The tools and procedures can be selected from the corresponding compartment or module within the "toolbox" to fit the circumstances of the assessment. The modules in the toolbox consist of sets of procedures, which have been identified as being part of a main core of thematic or disciplinary procedures, integrated into a unit which performs a major task or set of tasks within the driving forces-pressures-states-impacts-responses paradigm. Each modular array performs a set of core tasks and takes input from and delivers output to other modules. Modules can be activated and used independently, but the final assessment may depend on the integration of results obtained from several modules. In that sense, the flows of data and information should all be integrated. Decision-support systems are designed to aid the user in the integration of results.

The framework's modular structure is deliberate so as to facilitate bringing the necessary elements of data and information from the different capitals: i.e. the natural capital, the social capita, the human capital and the financial capital, which are the pillars of the livelihood systems, together for integration. These capitals translate into the integration of data and information from biophysical, socio-economic, cultural and demographic databases. These are all databases and information needed in the assessment process. The procedures for the assessment under the approach are based fundamentally on indicator variables and "proxies". However, the framework would use any "hard" data available, derived from detailed measurements (e.g. sediment plot data), whenever possible.

In practice, the framework does not specify a particular flow of assessment operations. There are multiple entry points to the assessment, depending on particular circumstances, and there can be several partial information products derived from and during the assessment. Thus, there is no specific sequence for operating the procedural modules. They can be used independently. While the framework structure is very inclusive, in order to conduct an assessment not all the modules need to be used, since the local circumstances of the country or region where it is applied will dictate what modules are relevant and needed.
The framework allows for the execution of land degradation assessment operations in such fashion as to permit that top-down operations (e.g. notably, operations based on remote sensing) and bottom-up operations (e.g. notably, field assessment procedures) can be harmonized and integrated into a map legend. Therefore, one does not take precedence over the other. Detailed field assessment based on measurements, observations and indicator variables in the filed are considered just as important in indicating land degradation at that given scale, as the changes of land cover that can be detected through satellite image interpretation at a much smaller scale. Their findings can be harmonized between top-down and bottom-up. Thus, the possibility of multiple entry points into the assessment.

3. The framework component tasks

The structure of the ESCWA framework consists of 12 major tasks or core sets of activities:

1. **Definition of area and scale**: Identify and delimit areas for the assessment and define the working and reporting scales.
D. **Select Indicators**: Identify (from the LADA list or LADA indicators DSS) the set of indicator variables relevant to the selected assessment scale. Include other local indicators and complement the indicators list as appropriate.
E. **Select methods, procedures and tools**: Select from the "toolbox" the applicable thematic module(s) containing the methods, procedures and tools needed for the assessment at the selected scale, according to the indicators identified.
F. **Collect existing data and identify data gaps**: Gather and compile existent relevant data (spatial and attribute) and databases, (including satellite imagery, if applicable), identify data gaps and compare to LADA recommended minimum datasets.
G. **Stratify or partition variability:** Stratify variability (bio-physical, socio-economic) in the area into relevant units (zones, terrain/landscape units, land use, etc.) to be assessed. These will be the objects of assessment.
H. **Design a data collection strategy for missing data**: Design a data collection strategy consistent with data needed and in agreement with technology, local capacities and desired accuracy by:
    1. Designing a statistically reliable sampling scheme on the basis of the strata or units and locate sampling sites based on the stratification.

2. Collect data in the field (if applicable) from designed sampling sites and surveys, for the relevant indicators and scale of the assessment.

I. **Analyze data**: Analyze data by applying the method and tools selected from the DPSIR framework "toolbox".

J. **Integrate results:** Integrate results using the decision support tool (whether the paper forms or digital decision-support system designed for this purpose) and establish causes, impacts and responses: Integrate findings and seek to establish causality, impacts on livelihoods, including the economic costs of degradation.

K. **Identify "hot spots" and "bright spots"**: From the integration of causes and responses to land degradation identify areas where degradation is being arrested and even reduced i.e. "bright spots and areas where degradation and degradation risk are high, i.e. "hot spots".

L. **Validate results and assess accuracy:** Undertake implementing ground validation and verification of results, including finding and reporting uncertainties and assessment of accuracy.

M. **Map out and report results**: Map the spatial distribution of land degradation by designing an ESCWA-explicit legend (or by adopting the LADA legend suggested in the framework), and report findings.

N. **Monitor changes over time**: Design a monitoring strategy consistent with data availability and in agreement with technology, local capacities and desired accuracy.

The twelve major tasks or core sets of activities suggested for the ESCWA region can be described more in detail in the following sections. These major tasks require for their completion of a set of decision support, analytical and modelling tools, which are bundled into three decision support systems, namely:

a). **Indicators Decision Support System (IDSS)**. This systems assists users with the selection of indicators of land degradation to be used in the assessment according to geography and social and cultural circumstances of the assessment and data abundance or scarcity.

b). **Methods and Tools Decision Support System (MTDSS).** This decision-support system assists users in selecting the most appropriate methods and tools, given a set of indicator variables to be measured or estimated, and according to circumstances of data availability and technical knowledge.

c). **Results Integration Decision Support System (RIDSS).** This decision support system assists users with integrating results coherent with the DPSIR components so that driving forces, pressures, states impacts and responses are identified and characterized. The results are also integrated into a mapping legend at a given scale.

The relationships between the 12 tasks and the three decision support systems can be seen in Figure 11. The generalized flow chart of all the modules in the DPSIR framework that are contained in the "toolbox" of methods and procedures for the assessment, is shown in Figure 12. This modular "toolbox" is central to, and at the core of the methodological framework, for it contains the methods, procedures and tools for the assessment divided into modular components which address major tasks (set of 12 core tasks). These 12 tasks are shown in small circles in the flow chart for the "toolbox" in Figure 12. A detail description of each module is too lengthy for this report.

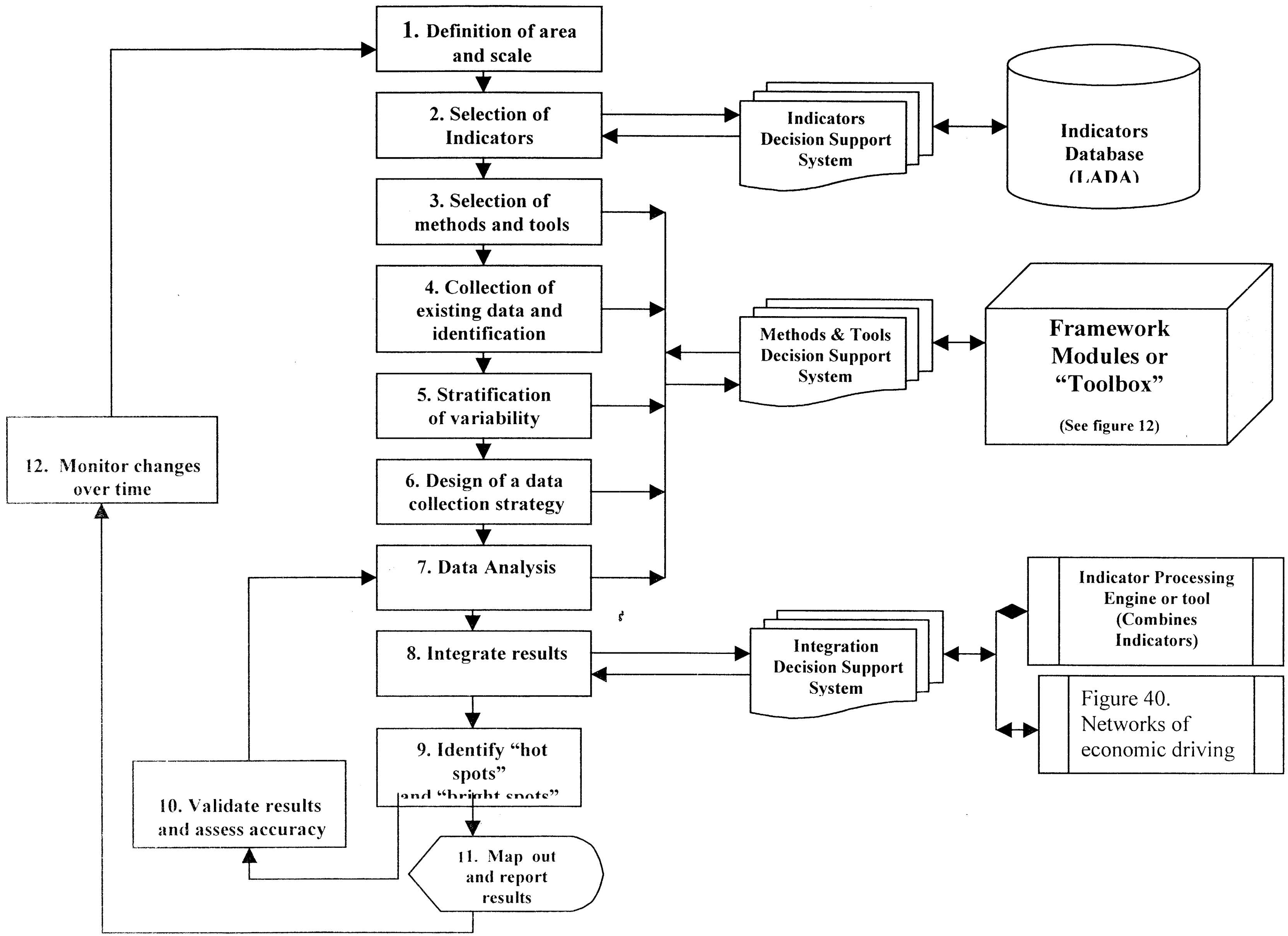
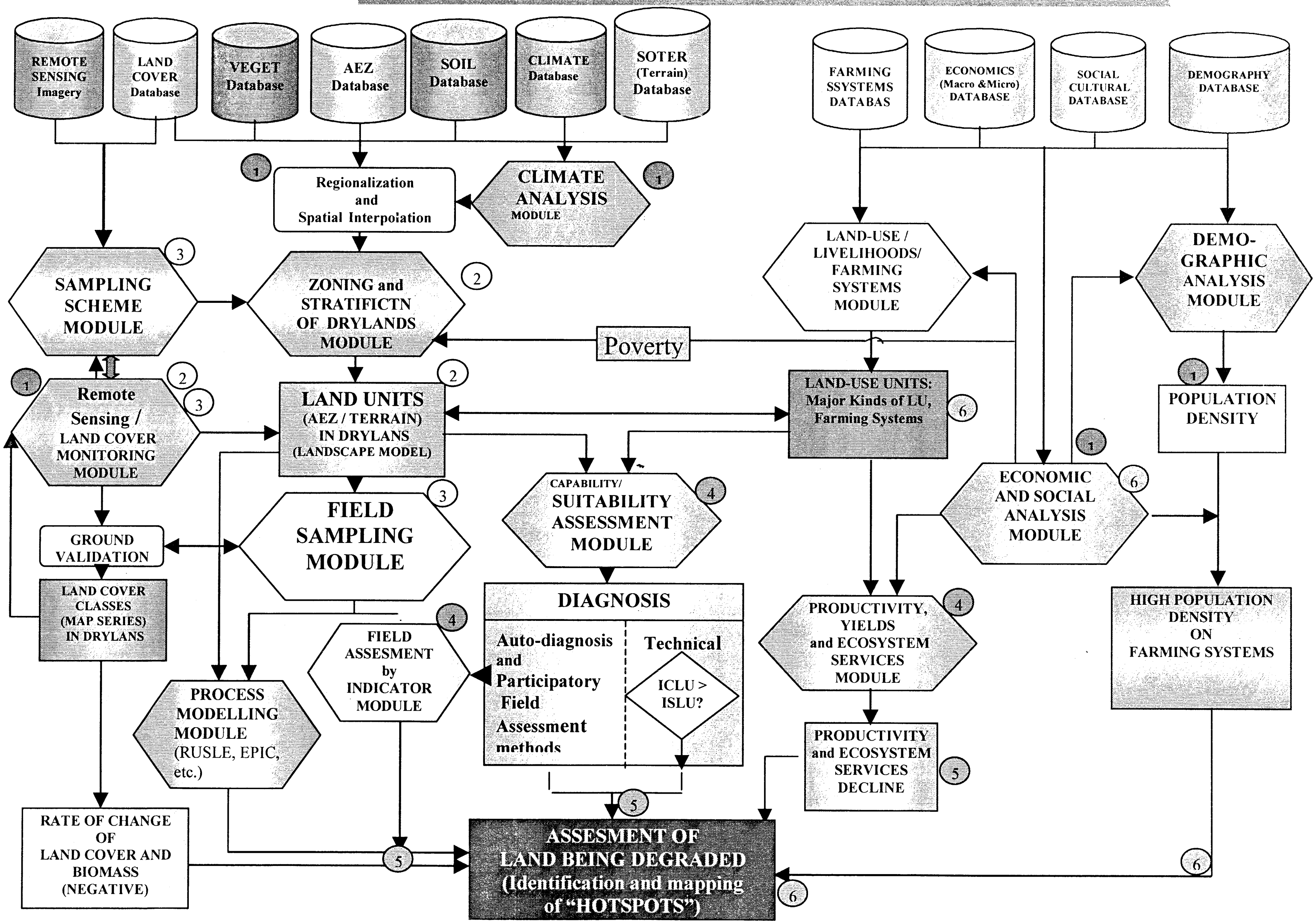


Figure 11. Core set of activities of the ESCWA methodological framework and their relation to decision support systems

Figure 12. Framework modules or "toolbox" for land degradation assessment methods



The decision-support systems envisaged as essential in the ESCWA framework and illustrated in Figure 11 should provide support to the assessment teams in order to arrive at important methodological and implementation decisions. These systems provide information and answers to fundamental user's questions. Some of the most critical questions are as follows:

- What is the appropriate set of indicators at the selected scale for an assessment?
- How are these indicators estimated/measured/observed?
- How are the values or categories of these multiple indicators combined?
- How are all kinds of factors and indicators integrated into an assessment?
- How is causality (i.e. driving forces and pressures) determined?
- How are the nature, extent, severity and impacts of land degradation reported in to a single standard characterization or legend?

The answers to such kind of questions can be related to the necessary decision-support systems, toolbox and databases part of the ESCWA framework. Figure 13 illustrates the relationships between these essential questions and the ESCWA decision-support systems and tools. The presence of decision support systems is fundamental to the selection of indicators, methods and tools for their measurement, analysis and integration into a given characterization scheme or mapping legend. The modular structure of the framework could not function without these decision support systems. The modular toolbox of methods and procedures and the database of indicators provide the substantive content, which is accessed and obtained through the decision support systems. Typically, a user after fixing the scale of the assessment will need the decision support systems to determine and access relevant indicators, the methods and procedures for their measurement or estimation and thenceforth for their analysis, combination and integration into an characterization protocol or assessment legend.

4. The role of Scale in the selection of methods and tools through decision-support systems in the ESCWA framework.

The ESCWA Framework considers the differences that exist between the indicator variables of land degradation at different scales of the assessment. Spatial and temporal scales are very important factors in determining the detail with which spatial variability can be resolved. Therefore, the choice of indicators and the results of the assessment depend directly on scale. It is clear that the indicators that provide evidence of the state of degradation at one scale (e.g. vegetation cover changes as detected from satellite imagery at a small scale) may not operate at another scale (e.g. soil sheet erosion at farm plot scale as evidenced by exposure of tree and shrub roots). Dependence on scale in decision-making about indicators, methods and tools for their measurement and analysis, forces scale to be a necessary entry point in any assessment. The determination of the scale for the assessment is an independent decision, usually made by the assessing team and often responding to policy priorities and seldom to technical considerations. Fixing the assessment scale reduces considerably the range of possibilities in the choice of indicators and of analytical tools, therefore focusing the assessment on only the relevant indicators, methods and tools that achieve meaningful results at such scale. To each scale, from national, regional, major basin, district or local, corresponds a set of relevant indicators and a set of methods, procedures and tools to measure or estimate. The proposed ESCWA decision-support systems and tools should provide answers to such scale-dependent decisions. The relationship between scale and decision-support systems in the ESCWA framework is illustrated in the diagram shown in Figure 14.

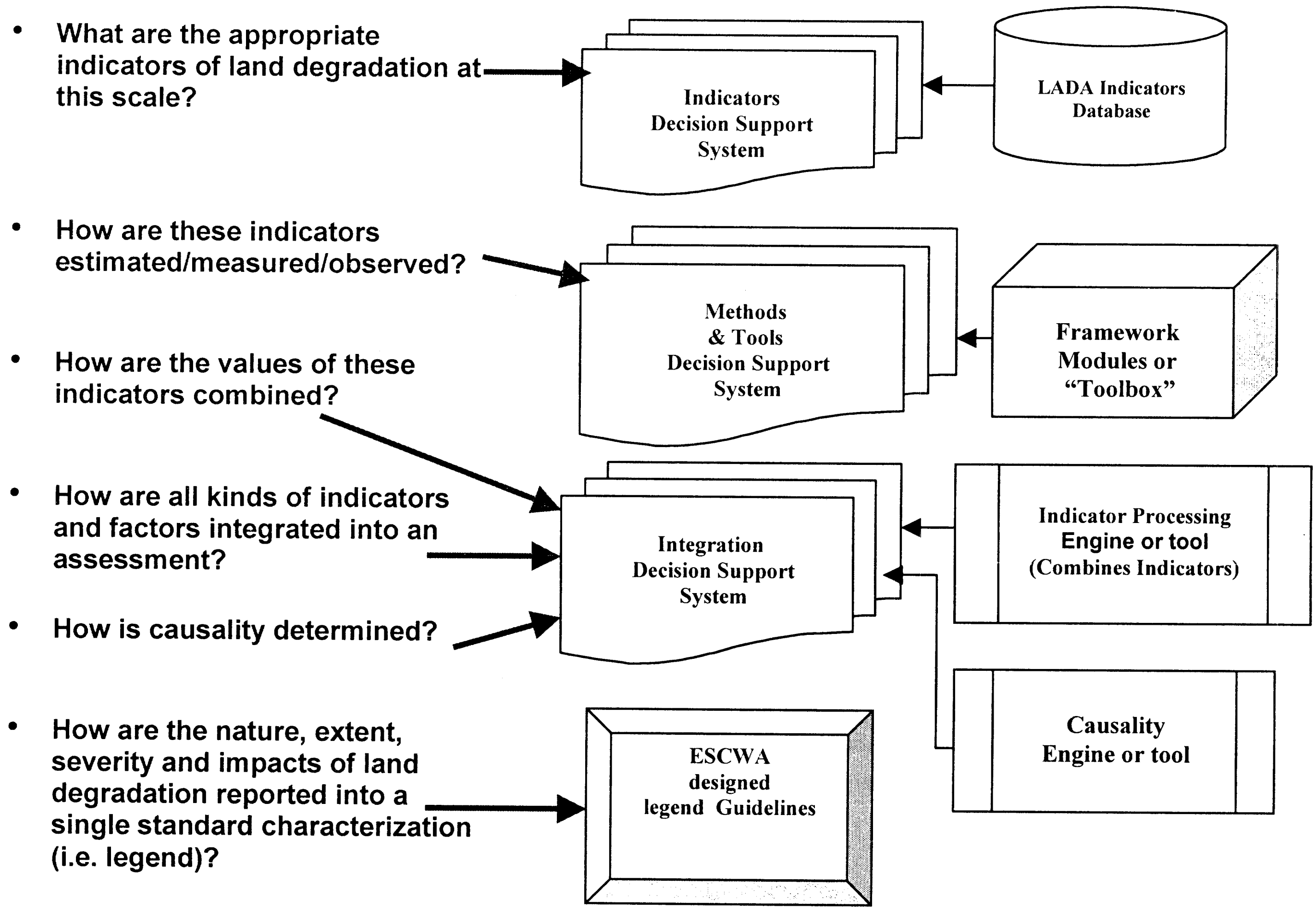


Figure 13. Support provided by decision-support systems, databases and tools to answer fundamental questions by users in the implementation of a land degradation assessment

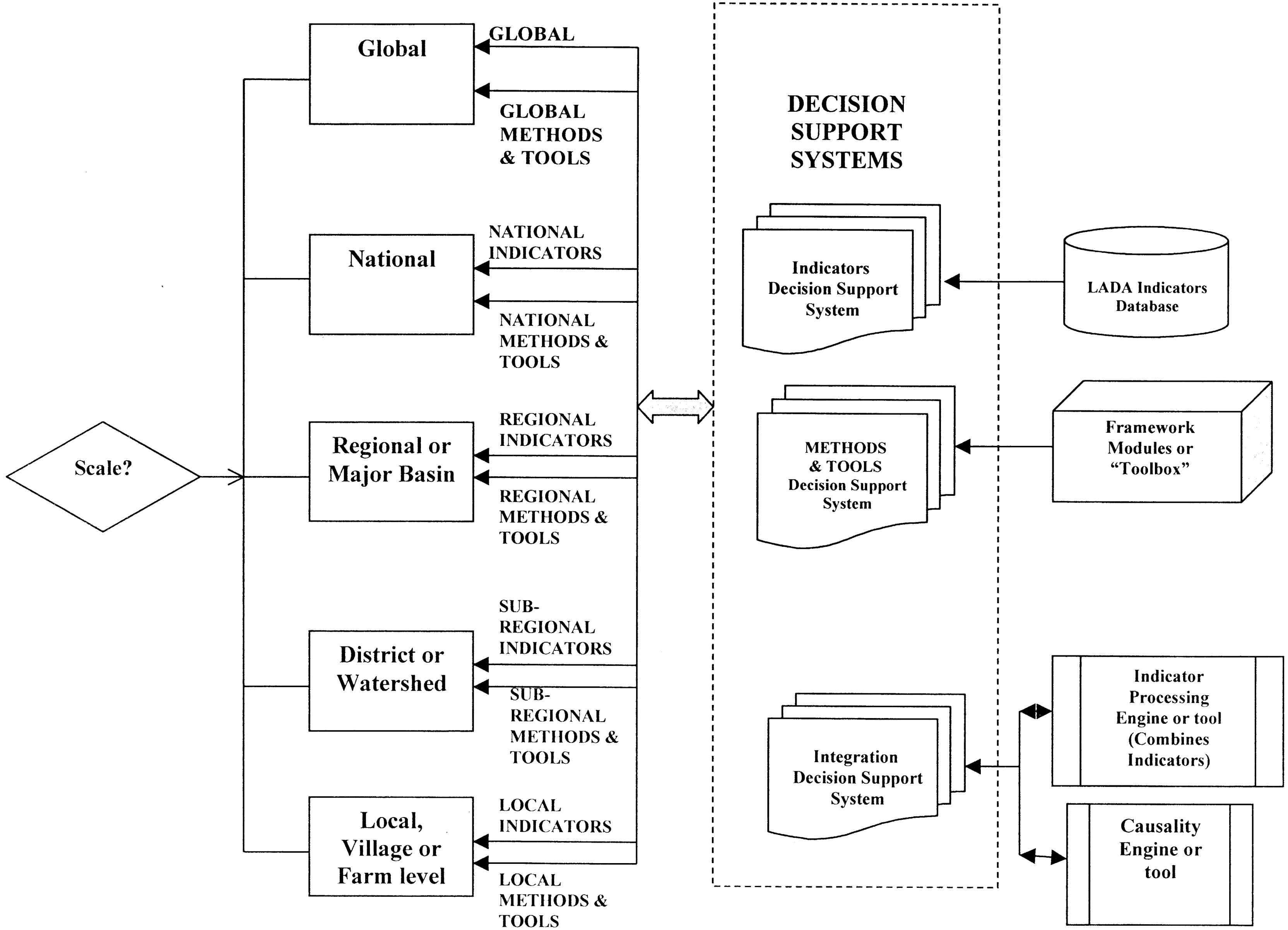


Figure 14. Scale-dependent decision support on indicators of land degradation and the methods, procedures and tools appropriate to the selected scale.

5. How to use the ESCWA framework

The use of the ESCWA framework requires, first, following the 12 tasks in the framework in sequence. The framework's 12 tasks provide greater detail on sequence of activities. These activities are assisted by the decision support systems (Figures 11 and 13). Thus, the ESCWA framework should be used as a modular or compartmentalised toolbox of methods, procedures and tools, whose access and use are assisted by the decision support systems part of the framework. So, depending on the situation of data, expertise and scale for the assessment, users must use of the decision support systems to obtain guidance as to indicators, methods and procedures and then analysis, integration and report of findings. The scale must be chosen first, then the corresponding set of indicators that are suggested (i.e. from the Indicator Decision Support System; Figures 11 and 13) as being relevant to the scale, data and other circumstances of the assessment. Once the set of relevant indicators is chosen, the selection of the required methods, procedures and tools for their measurement, estimation, observation and/or modelling is carried out, assisted by the Methods and Tools Decision Support System. Once the selection of methods, procedures and tools is finalized, the modular "Toolbox" is accessed and methods and tools identified and retrieved for their application to data. The ESCWA framework modular toolbox is compartmentalised into modules or sections. Its modular components are described in a synthetic way in Figure 15, which is a synthesis of the more detailed flowchart in Figure 12. From this toolbox specific methods and tools can be accessed and specific methodological description obtained. The decomposition of the basic over-generalized modules (as illustrated in Figure 15) is part of the framework's "toolbox". The individual component modules and their respective sets of analytical operations (Figure 12), is at the core of methodological framework design.

The details of each method, procedure and tool within each of the modular components are substantial and far too large to be provided here. The complete methodological framework "toolbox" is depicted in the form of a flowchart in Figure 12. The modular components (represented by hexagonal shapes), the connections between them and between them and the databases (cylinder shapes) and between the modules and external operations (oval shapes) and between all and the resulting information products or outcomes of a modular procedure (rectangular shapes) are charted as analytical paths in Figure 12.

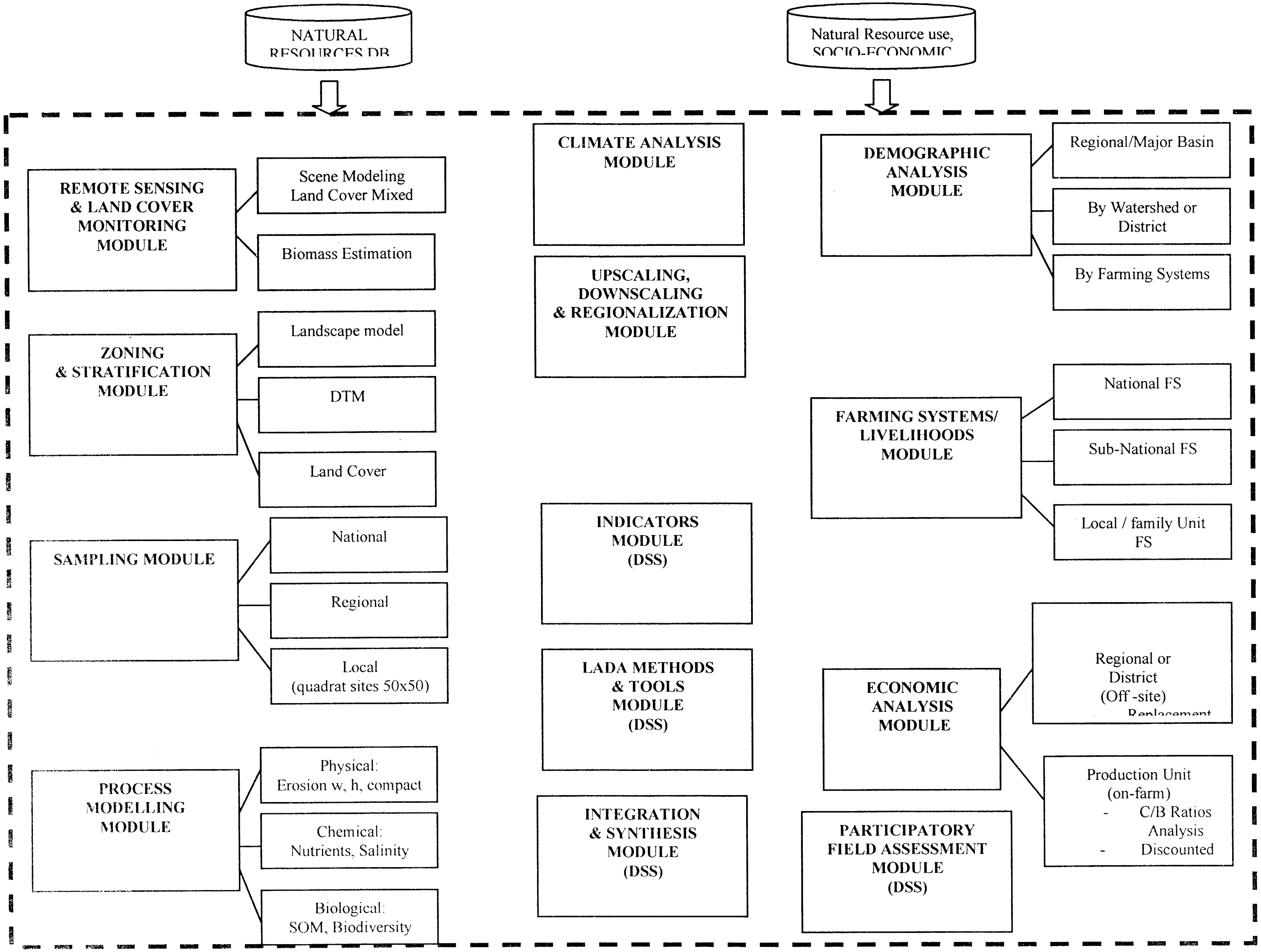


Figure 15. A more synthetic view of the modular “toolbox” of methods, procedures and tools

6. Decision Support System for Results Integration and Networks of Causal Chains

Once indicators are selected with help from the Indicators Decision Support Tool and the selection of the methods and tools for their measurement and processing and analysis supported by the Methods and Tools Decision Support System linked to the "toolbox", there is still a pending problem, that of the integration of results into an assessment. Since numerous indicators can be used at any given time during the assessment, user support will still be required to enable the consistent, comparable and replicable integration of the status of the indicators into an assessment meaningful for policy formulation. To avoid oversimplification of a rather intricate process it is suggested that such integration is carried out in a dedicated Integration Decision Support System (IntDSS). This system should have two main components, one for processing the results of the values of indicators obtained from the assessment and determine the status of degradation of land, the other for finding the causes (causality) of land degradation. Thus, these components are:

- Indicator Processing Engine or Tool (IPE)
- The Causality Engine or Tool (CausE)

These components are clearly illustrated in Figures 13 and 14 above.

(a) Indicator Processing Engine (IPE)

The IEP should be linked to the IntDSS and should provide a highly interactive support to users in selecting the method by which indicator data, already measured and obtained from field assessment, should be combined. There are a variety of approaches to the combination of indicators. Namely:

- **Using weighting methods** to assign "weights" to individual indicators according to either, prescribed sets of weights by the system or user-suggested weights, making the process more participatory. Examples of this type of IntDSS is the prototype designed by the "**Desertlinks**" project (Desertilinks, 2004).

- **Using decision-trees** to assign both priority and importance to individual indicators and their ranges of values in order to arrive to a final assessment. There are no many examples of the use of decision-trees, other than in land suitability assessment. However, Figueroa-Cano and Ponce-Hernandez (2000) showed how indicators could be coded into a decision-tree for assessing "sustainability". This approach allows for the consideration of both, biophysical and socio-economic indicators measured at, the ratio, interval and nominal scales. It must also be mentioned that there is widespread knowledge of decision-trees as a useful tool for land evaluation in many parts of the developing world and that its adoption for degradation assessment should not represent a technological barrier to overcome.

- Using more sophisticated methods such as Artificial Neural Networks to combine the attributes of indicators. These, due to their complexity and degree of reliance on high technology are deemed not suitable for being part of the IPE.

(b) Causality Engine or Tool (CauseE)

The causality engine or tool is linked to the integration decision support system (IntDSS) in order to provide support, once the indicators have been combined into an assessment, on the finding of causal factors of degradation. Since the ESCWA methodological development is predicated on the

DPSIR approach and on the finding and characterizing land degradation states and their causes, finding causality becomes paramount to the results of the assessment.

Establishing causality between the states of physical, chemical and biological land degradation and the driving forces and pressures causing them cannot be a deterministic approach since there are far too many factors at play as possible causes and their effect on final state of degradation is either, not yet completely understood or it changes with the socio-political, cultural and economic contexts. Therefore, there will always be a probabilistic element in ascertaining the causality of a degradation state, regardless of the assessment scale. Two approaches to establishing causality can be part of the causality engine or tool, which in turn is part of the Integration Decision Support System (IntDSS). These approaches are:

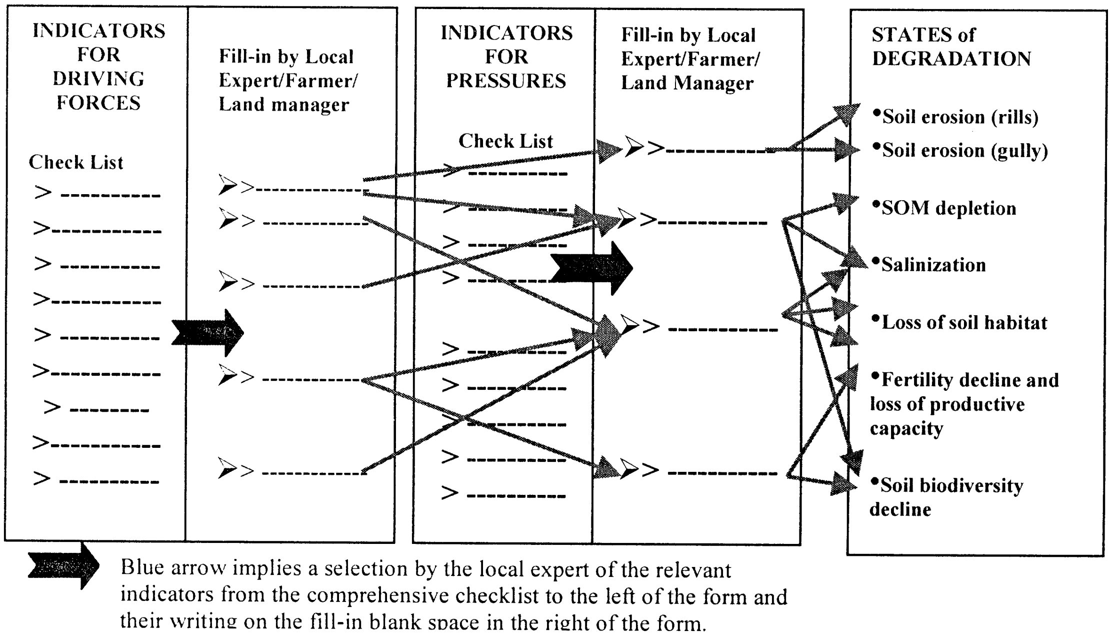
- Analogue or "manual" approach (i.e. paper forms) based on expert knowledge.
- Automated approach based on a digital causality engine or tool based on networks of causal chains (NCC), which could be accessed via web.

Both approaches are discussed in more detail below.

Manual or Analogue Approach to finding causality. Finding causality under this approach entails a manual procedure with the creation of "fill-in" paper forms that include a comprehensive list of indicators of driving forces and pressures. With these forms a local expert or a knowledgeable assessor of the geographic area chooses the indicators that are considered relevant and writes them down on the blank space to the right of the form. This is done for each of driving forces and pressure indicators. Then, the local expert connects driving forces to pressures by drawing by hand on the same paper forms, connecting arrows that link the indicators selected from the lists. These indicators were observed/measured or data on their status are available. The pressures are linked in the same fashion to the indicators of the state of land degradation, according to the expert's own experience and knowledge of the geographic area where the assessment is being performed, and supported by data from interviews, documented evidence in reports and other available information. The manual or analogue form to establishing causality through local expert judgment is illustrated in the diagram of Figure 16. The requirements for the implementation of this method at the local level are minimal. They consist of a series of pre-formatted, fill-in paper forms and the identification of an experienced local expert. The forms should contain knowledge in the form of a comprehensive list of indicators of driving forces and pressures and of the measured states of degradation.

Automated Approach to finding causality through Networks of Causal Chains (NCC) built in the Causality Engine (CausE). Networks of Causal Chains (NCC) have been used successfully in a variety of ecological instances to determine the possible and probable causes of a given state of a system (e.g. Pearl, 2000; Cloern, 2001; Borsuk et al, 2001, 2002 and 2003; Weidl et al, 2003). Such networks are constructed on Bayesian theory. Bayesian networks for causal analysis may seem complex for the unaccustomed reader. However they are commonplace in many other disciplines where causality and probability of causality are to be found. The Causality Engine (CausE) or Tool is to be based on Bayesian Networks of Causal Chains (NCC). A prototype of NCC can be designed and develop readily as a software tool.

Figure 16. Manual or analogue method for finding causality through linking driving forces and pressure indicators to states, by drawing causal arrows (in red colour) by experienced local experts in the geographic area of the assessment. Note: The approach employs paper forms and lists of relevant indicators selected by the expert in the fill-in space to the right of the list.



The Bayesian networks of causal chains are to be built in a highly interactive way by the user of the CausE tool. The causal engine (CausE) will have, built-in, the algorithms for allowing the user graphically and interactively calculating the linkages and establishing the networks of chains of causality linking driving forces to pressures and onto states of land degradation. An example of the NCC is illustrated in Figure 17. In this example the links represent autonomous mechanisms as described by probability functions. Each set of arrows pointing to a giving node Xi represents a function of the form:

$$X_i = f_i(pa_i, \xi_i)$$

Where pa_i are the parents of the node X_i; fi are the probability functions and ε_i are independent random disturbances. The outcome of the process in the Causal Engine using the NCC is the Bayesian or "Markov Blanket" of causistic variables or "strongly relevant causistic variables". A very illustrative example of the application of the causal chains approach to land degradation assessment at local scale was given in the report by Dixon (2003), working in two different dryland conditions in Mexico. In that work the causal chains were obtained manually from local expert consultation via interviews and the application of field questionnaires. The causal chains found in that case study are illustrated with an example of a causal chain in a natural capital in Figure 18. The driving force is the demands for primary productivity of the land resulting in a variety of related pressures, notably, the recess of land cover with the resulting exposure to soil erosive forces. A variety of degradation states result from such pressures as illustrated in Figure 18. The effects that different states of land degradation could have on peoples' livelihoods and the responses generated by farmers and land users to such impacts are also illustrated in Figure 18. The work of Dixon (2003) in Mexico also illustrates how the same "causal chains" procedure can be applied to establish the impacts of land degradation.

The application of all elements of the methodological framework for land degradation assessment in the ESCWA region, described in all preceding sections of this document, is implemented through a case study. Lebanon was selected as a country in the region to implement such case study. The following sections of this report describe the results of the application of the ESCWA methodological framework for land degradation assessment to lands of Lebanon.

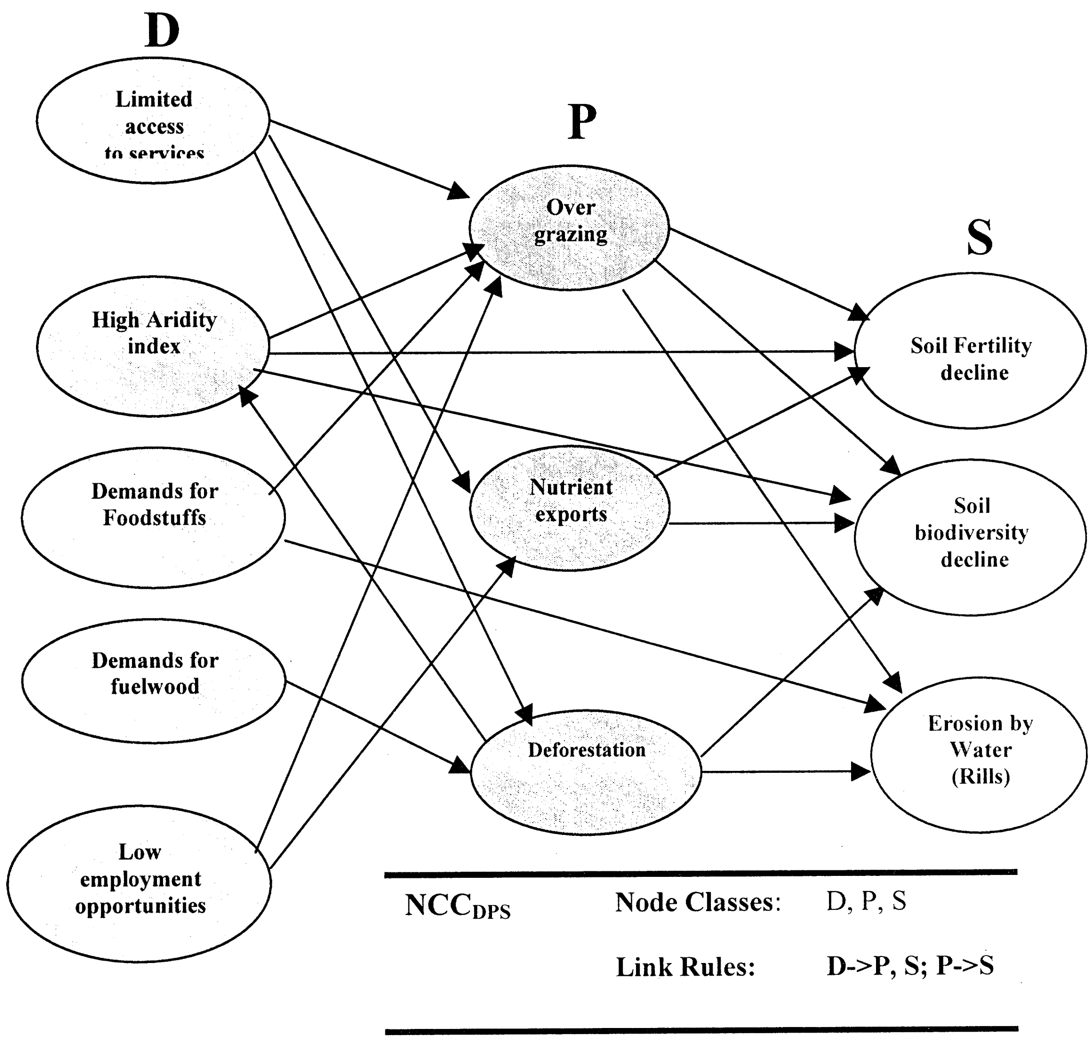


Figure 17. Networks of Causal Chains (NCC) resulting in the states (S) of land degradation highly likely caused by the pressures (P) and the driving forces (D).
Note: The example illustrates the workings of the Causality Engine (CausE) in establishing through Bayesian networks the causality of P and D (these are known as the "Markov Blanket" of causistic variables or "strongly relevant causistic variables")

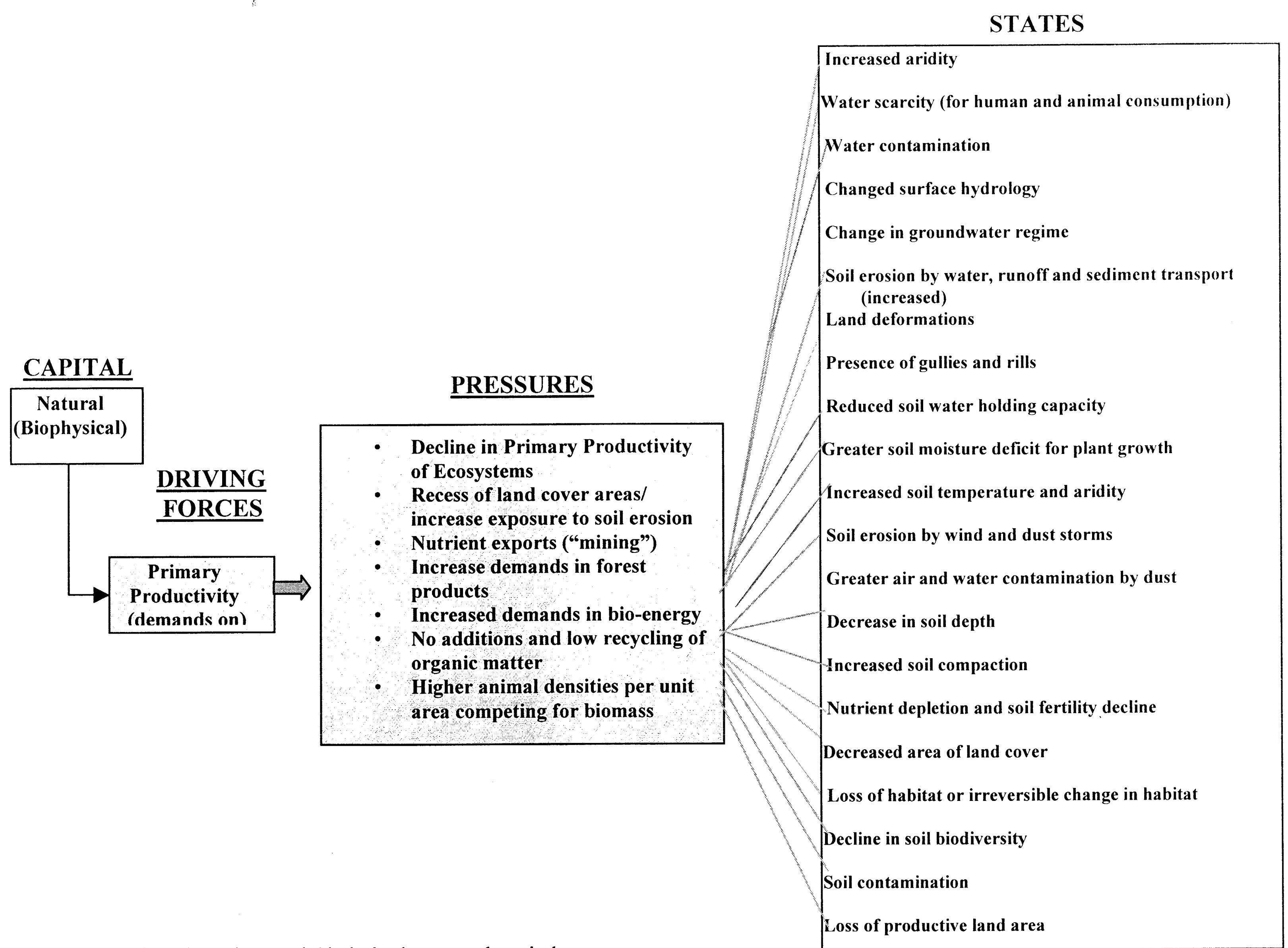


Figure 18. Example of a selected Causal Chain in the natural capital.
Note: Driving Force is demands for primary productivity, related Pressures e.g. recess of land cover/exposure to erosive forces with corresponding resulting states of degradation and impacts in "El Alegre", San Luis Potosi, Mexico (after Dixon, 2003).

7. *Selection of indicators, integration of causes and design of a mapping legend.*

The proposed indicator-based methodological framework for the assessment of land degradation in the ESCWA region forms the basis of the field implementation of assessments. The selection of indicators is crucial to the success of the assessment. Prior chapters of this report have described the role of automated decision support systems to aid in the selection of indicator variables relevant to the area of study. These decision support systems are thus far conceptual and once developed they will rely on the existence of a fairly large database of indicators. In the absence of an automated decision support system for indicator selection, this is to be achieved manually in order to apply relevant indicators to the study area of concern.

Prior work for the LADA project at FAO (Snel and Bot, 2002) yielded a compilation of a comprehensive list of potential indicators for all areas of the hyper-arid, arid, semi-arid and dry sub-humid areas of the world. This list of indicators (Appendix A) was found to be too lengthy and in some cases irrelevant to the context in which they were to be applied. Therefore a selection process of relevant indicators was performed on the original list of Snel and Bot (2002). Selected indicators used in this assessment were derived from that compilation and from other sources (Stocking and Murnaghan, 2001). The selection should be based on the applicability of each indictor at the scale of study, given the region's climatic, biophysical, socio-economic and production system characteristics. The indicators should be organised by expected data source, including interviews, field observations and measurements, and printed reference materials, as shown in Table 7. After a comprehensive selection of indicators to those considered relevant to a case study in the ESCWA region, the list of selected indicators is presented in Table 7.

The measurement, observation or modelling outcomes to estimate the status of such indicators require a sampling process. Sample locations in the area of concern can be selected using a well thought out and a statistically reliable sampling design. Typically, a modified stratified random sampling scheme could fit well the purposes of the sampling, where the strata are landscape or physiographic units (Land Systems and Land Facets), or any other geographic unit that could warrant the assurance of internal homogeneity of the units. Coordinates of sampling locations can then be selected randomly within strata (land facets) from a table of random numbers, but attempting to sample deliberately, areas of evident degradation. The sampling can be modified based on field conditions of site accessibility, farmer availability and time constraints. Reality will dictate ultimately the final positions of the fields that are to be sampled. Moreover, since interviews with farmers are needed in order to obtain information of many of the indicators, the sample will be biased depending on the availability of farmers for interviewing. Word of mouth and as many contacts with farmers that can be established through previously interviewed farmers, can potentially create more of a geographical or social bias through a 'snowball sampling' scheme. Such is reality in the field and the assessor should adapt the sampling scheme to these realities.

Table 7. Indicator variables selected for an assessment at regional to local scale for the ESCWA region	Potential Data Source
Rills	Field Survey or reference
Gully	Field Survey or reference
Pedestals	Field Survey or reference
Plant/tree root exposure	Field Survey or reference
Fence post/other exposure	Field Survey or reference
'Waterfall' soil loss	Field Survey or reference
Rock exposure	Field Survey or reference
Tree mound	Field Survey or reference
Build up against barriers/tree trunk/ plant stem	Field Survey or reference
Sediments in drains	Field Survey or reference
Enrichment ratio	Field Survey or reference
Solution notches	Field Survey or reference
Soil/rooting depth	Field Survey or reference
Armour layer depth	Field Survey or reference
Structure	Field Survey or reference
Consistency	Field Survey or reference
Infiltration	Field Survey or reference
Water holding capacity	Field Survey or reference
Differential crop growth pattern	Field Survey or reference
pH <6 or >7.5	Field Survey or reference
Salinity – colour change, structure, 'dusty' surface	Field Survey or reference
Sodicity – resistant species	Field Survey or reference
Alkalinity	Field Survey or reference
Toxicity/contamination – plant deficiencies	Field Survey or reference
Nutrient deficiencies	Field Survey or reference
% Land cover	Field Survey or reference
Soil temperature & aridity	Field Survey or reference
Above and below-ground soil biomass	Field Survey or reference
Soil Moisture	Field Survey or reference
Biodiversity – above ground flora & fauna, - below ground flora & fauna	Field Survey or reference
Change of permanent waters to seasonal or periodic	Field Survey or reference
Drought frequency	Reference, Field Survey
Increasing in water table depth	Field Survey or reference
Change in annual rainfall	Reference, Field Survey
Evidence of atmospheric contamination & effect on plants	Field Survey
Terrestrial carbon depletion	Reference, Field Survey
Change in annual air temperature	Reference, Field Survey
Decline of crop yield	Field Survey
Increased drought frequency	Reference, Interview
Average air temperature changes	Reference, Interview
Increased frequency of erosive rainfall events and surface runoff	Reference, Interview
Increased frequency of high velocity winds causing dust	Reference, Interview
Unfavourable rainfall quantity, intensity and distribution	Reference, Interview
Increased water losses through runoff and evapo-transpiration	Reference, Interview
Increased water demands by plants, animals and humans	Interview
Increase aridity and favourable conditions for soil compaction and hardpan formation.	Reference, Interview
Volcanic eruptions and their effects on the landscape	Reference, Interview
Earth-quakes	Reference, Interview
Tornados	Reference, Interview
Dust storms and their erosive effect	Reference, Interview, Survey
Landslides	Reference, Interview
Fire	Reference, Interview
Terrain roughness (restrictive rapid topographical changes)	Reference, Interview, Survey
Slope steepness	Reference, Interview, Survey
Position on slope (unfavourable)	Reference, Survey

Mining, quarrying and extracting activities (e.g. clay) and	Reference, Interview
Earthworks modifying the landscape unfavourably	Interview
Weak soil structure and texture	Survey
Rockiness and stoniness (surface and sub-surface)	
Soil depth (restrictive)	Survey, Interview
Depth to water table	Reference, interview
Pressures by High Animal and/or Livestock Densities (e.g. decreased biomass, soil compaction, etc.)	Survey, interview
Surpassed animal carrying capacity of grasslands/rangelands/forests.	Interview, survey, reference
Poor livestock and forage (grasses) diversity	Survey, interview
Invasion of excessive animal populations	Interview
Habitat recession and disappearance	Interview, reference, survey
Decline in Primary Production of Ecosystems	Interview
Increased demands of forest products	Interview
Recess of land cover area/increased exposure to erosive forces	Interview
Increased demands of bio-energy	Interview
Nutrient exports ("mining")	Interview, survey
Soil organic matter and Carbon depletion	Survey, interview
Conflict & violence (presence & frequency)	Interview
Volatile political and rural policy system	Interview, reference
Crop yield decreases in past 3 or more years	Interview
Frequency of total crop failures	Interview
Low value of production/unit area	Interview
Increase in deficit of production of staple foodstuffs locally	Interview
Low per capita calorie/protein intake	Na
% Malnourished (underweight) rural children under 5	Interview
Change in water availability per capita	Interview
Increased distance to water supply & collection	Interview
Increased time spent in collecting water	Interview
Deterioration of water quality (increased turbidity and /or contamination)	Interview
Low % of rural population with access to water	Interview, reference
Affordability and accessibility to main energy source (unfavourable to biomass)	Interview
Changes in main energy source	Interview
Main fuel sources	Interview
Migration (permanent/seasonal)	Interview
Poverty gap index/income	Reference
Land tenure constraints (type, access)	Interview
Access to common cultivable land Ha/farmer	Interview
Population growth rate (higher demands on resources)	Reference
Population density (high pressures on the land and resources)	Reference, survey
Age/gender distribution & occupation (unfavourable to land stewardship and lack of involvement of women)	Reference
Aging farming population and increase in young landless people	Interview, reference
Migration of the young and /or poor participation in rural community affairs.	Interview
Rural infant mortality rate (per 1000 live births)	Interview
Change in non-farm employment	Interview
Unemployment rate	Interview, Reference
% National budget in rural and agricultural development	Reference
Lack of personal investment in the land and land activities	Interview
Lack or low government investment in land programs in rural areas.	Reference Interview
Low level of Government/institutional staff involvement in agricultural research and extension	Reference Interview
Research and investment focus on crops vs. resources	Reference
Credit availability (lack of)	Interview
Presence/use of banking institutions (lack of)	Interview
Access to markets of input & output supplies (distance, transportation, type)	Interview
Uncertainty of land tenure	Interview
Unregulated, unrestricted use of common lands	Interview, survey

Tax exemptions i.e. for large-scale farms.	Interview, Reference
Land tax or incentives for certain land use types of high intensity.	Interview, Reference
Absence or non-enforced by-laws on land-use and protection	Reference, Interview
Legislation for natural resource management (absent or non-enforced)	Reference
Globalisation, trade agreements and barriers unfavourable to small, self-sustaining (non-export) farmers, or limiting export/import opportunities to them.	Reference, interview
Manipulated rural investment policies and exchange rates to favour exports.	Reference
Policies to reduce farm income volatility i.e. produce	Reference, interview
Price guarantees	Interview
Credit schemes favouring a certain produce	Interview, reference
Introduction of untested and unsuitable land use types	Survey, reference, interview
Farmer groups/associations/co-operatives (absent or weak)	Interview
Lack of knowledge of institutional frameworks and support	Interview
Ignorance of regulatory frameworks	Interview
Cumbersome requirements of institutions & bureaucracies	Reference, interview
Absence or weak natural resource institutions	Reference, Interview
Density/type of road networks (unfavourable or poor)	Survey, interview
Availability/accessibility of public transport (lack of)	Interview
Lack of stream/storm/runoff control structures	Survey interview
Water distribution system (adequacy or absence)	Survey, interview
Sewage/road runoff collection & treatment (adequacy)	Interview
Access to latrines	Interview
Waste disposal type, location, proximity to population (absence or adequacy)	Interview
Low literacy rate and education	Interview, Reference
Difficult access to schools	Interview
Availability of extension services/agricultural education	Interview
Availability of environmental education (lack)	Interview
Lack of land stewardship	Interview
Lack of livestock management culture	Interview
Lack of sexual /family planning education	Interview, Reference
Days/year unable to work on land due to illness or poor health	Interview
Indigenous technical knowledge of land management & resource extraction	Interview

(a) *The field assessment forms and field interviews through questionnaires*

The stratified random sampling of farmer's fields and their interviews will be conditioned to the accessibility and availability of farmers/ herders and their willingness to participate in the assessment. Consequently, the sampling scheme can suffer modifications to accommodate for such availability, accessibility and willingness. Spread of the sampling process through word of mouth from the authorities in the community (farmer's groups) can enable for a stronger recruitment, hence modifying the original sample to available and willing farmers and their lands.

Two forms of data and information capture can be employed in the field to obtain information about the status of indicators in the area of study:

- Interviews through open-ended and closed questionnaires
- Field forms for recording the state of indicators of land degradation

The interviews should be designed to explore the range of perceived circumstances by farmers and herders, leading to the identification of driving forces and pressures from the five capitals. These questionnaires also can provide an opportunity to get information on and characterize the farming systems and sub-systems of the family group in turn, together with their coping strategies against the deterioration of resources and their responses to the impacts of land degradation on their livelihoods. Measures of productivity from farmer's/herder's lands (e.g. crop yields), their variability over time and the factors causing their decrease (e.g. drought, soil erosion, etc.), according to farmer's understanding, should be obtained from the interviews and the observations in field forms. The questions in the questionnaire should aim at gathering information of all possible circumstances contributing to the state of land degradation and its impacts on the livelihood of farmers as self-diagnosed by the farmers themselves.

The second type of field forms should contain more specific formats for gathering biophysical characteristics of the environment of the lands represented by the sampled plots. This part of the assessment should include site variables, all the indicators selected, including with them direct measurements of dimensions (length, width and depth over many cross-sections) of erosion structures such as rills and gullies, and other sheet erosion indicators present in the land plot being sampled.

In summary, the field sampling for the observation and measurement of indicators should include:

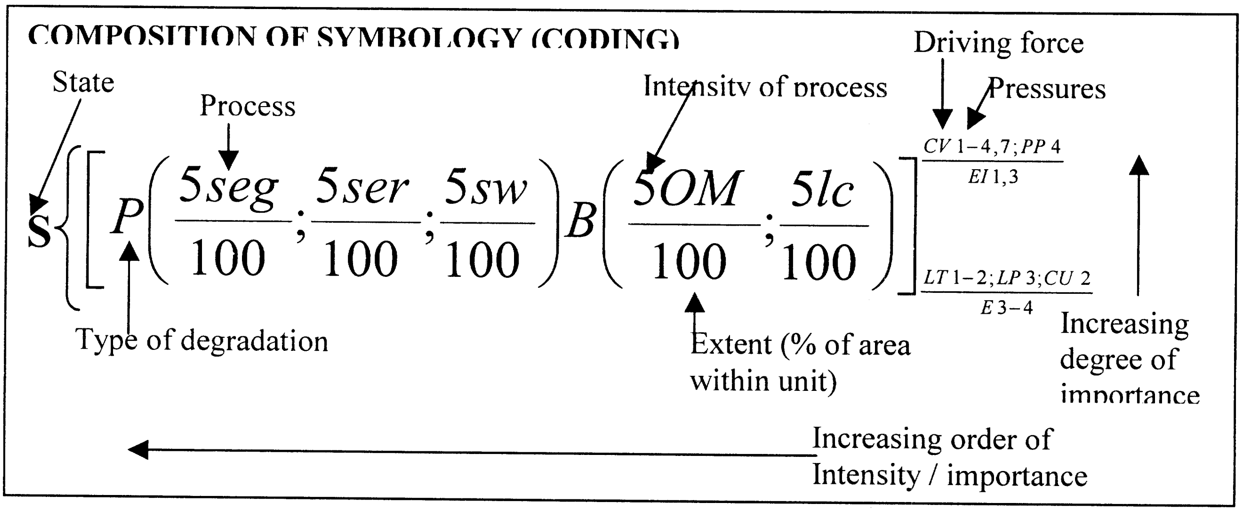
- Interviews with individual farmers and/or families regarding their household, socio-economic activities and farming systems, using both open and closed-ended questions;
- Physical surveys of land plots, observing and measuring both, qualitative and quantitative indicators of land degradation, and facilitating a participatory auto-diagnosis process where farmers/land users identify and discussed degradation processes and problems;
- Physical surveys of the rangelands (i.e. non-agricultural plots), observing and measuring both, quantitative and qualitative indicators of land degradation (using the same field forms as above);
- Informal interviews with municipal, provincial and federal officials in relevant governmental agencies and NGOs regarding policies and programs at their respective levels of government; and
- Collection and assimilation of printed information and data, and other reference materials.

(b) Design of a legend for mapping land degradation under the DPSIR approach.

The need for a convenient legend to express assessment results becomes quite apparent. The legend is also a focal point for integration of the DPSIR data and information gathered from the field interviews and observations and measurements of field indicators. The central principle of the legend is that in order to integrate all the elements of the DPSIR approach and the indicators of the state (type and intensity of degradation) the creation of a series of codes is needed. These codes should reflect, first, the type of degradation occurring, namely: physical (P), chemical (C) and biological (B). In turn, the physical processes can be grouped in terms of on-site and off-site processes, and those processes causing land deformation (e.g. rills and gullies). Chemical and biological processes should be also coded. The list of coded processes is not comprehensive and only relevant degradation processes operating in the studied area should be accounted for in the legend. However, using the same organization principle other processes relevant to any other given area could be coded.

The degree of intensity of the acting degradation process should be given integer numerals, and the spatial extent of the process with a given intensity should be coded in terms of percent units of the total area unit being assessed. Then the codes should be organized in terms of the type of degradation as coefficient, followed by one or more fractions. The numerator of the fraction is made up by a numeral indicating the intensity of the process, followed by the code of the type of process. The denominator of the fraction indicates the spatial extent of that type and degree of degradation process. Processes within one type (physical, chemical or biological) are enclosed in brackets. Once all the types of degradation and their processes, intensities and extents are included, a rectangular bracket closes the fractions and their coefficients. The causes of the type, intensity and extent of land degradation (i.e. driving forces and pressures) should be coded together outside the rectangular brackets, to make sense to the causes of the type, intensity and extent of land degradation. So, the driving forces are coded with capital letters, and the pressures are coded with integer numerals. Both, driving forces and pressures should be identified in the area from interviews with farmers, policy-makers, government agencies, NGOs and from documented literature. These should then be coded so as to be included in the mapping legend. It is understood that in each area these codes might be slightly or considerably different. However, the same organizing principle can be used to substitute or add to the original list. These driving forces and pressures are identified from applying the DPSIR chart in Figure 10 above, or the manual checklist in Figure 16. The final composition of the legend is attained by integrating the coded driving forces and pressures, as two fractions, one as exponent or "power" of the rectangular bracket, representing the driving forces and pressures with the greatest importance in determining the state of land degradation. The fraction at the bottom of the rectangular bracket represents the driving forces and pressures with the lesser degree of importance in determining the state of land degradation for a given area being assessed. So the degree of importance on D and P increases from bottom to top and from right to left. Admittedly, the codes are arbitrary and not universal. However, they could be changed, as long as tabulated information of the coding system accompanies the legend used to map out land degradation using the proposed legend system. Figure 19 illustrates the coding system to be used in the assessments of drylands. Table 8 shows a list of the codes used for the driving forces and the pressures identified and for use in the assessment of areas in a case study accompanying this report.

Figure 19. Legend components for mapping LADA assessment results



TYPE OF LAND DEGRADATION

P = physical **C** = chemical **B** = biological

DEGREE OF INTENSITY

1 = very slight
2 = slight
3 = moderate
4 = intense
5 = very intense

EXTENT

% of area of land unit assessed

PROCESSES OF PHYSICAL LAND DEGRADATION (P)

PROCESSES (on site)
se = soil erosion by water (sheet erosion)
sw = soil erosion by wind (sheet erosion)
co = compaction
cr = crusting and sealing

PROCESSES of land deformation
ser = soil erosion by water (rills)
seg = soil erosion by water (gully)

PROCESSES (off-site)
sed = sediment deposition
sefl = flooding
sec = water contaminated by erosion
swd = deposition of dust

PROCESSES OF CHEMICAL LAND DEGRADTAION (C)

f = soil nutrient and fertility depletion
sa = salinity
na = alkalinity
h = acidity
tx = toxic compounds (pollutants in soil matrix)
wt = solid wastes (soil surface)

PROCESSES OF BIOLOGICAL DEGRADATION (B)

lc = loss of land cover & biomass
om = organic matter
bio = loss of biological diversity

Figure 19 Continued. Legend components for mapping Lada assessment results

Table 8. Codes for driving forces and pressures to use in the mapping legend.

CODE	DRIVING FORCES	PRESSURES	CODE
CV	Climatic Variability	Increased drought frequency	1
		Average air temperature changes	2
		Increased frequency of erosive rainfall events and surface runoff	3
		Increased frequency of high velocity winds causing dust	4
		Unfavourable rainfall quantity, intensity and distribution	5
		Increased water losses through runoff and evapo-transpiration	6
		Increased water demands by plants, animals and humans	7
		Increase aridity and favourable conditions for soil compaction and hardpan formation.	8
ND	Natural disasters	Volcanic eruptions and their effects on the landscape	1
		Earth-quakes	2
		Tornados	3
		Dust storms and their erosive effect	4
		Landslides	5
		Fire	6
AL	Adverse Landscape conditions	Terrain roughness (restrictive rapid topographical changes)	1
		Slope steepness	2
		Position on slope (unfavourable)	3
		Mining, quarrying and extracting activities (e.g. clay) and	4
		Earthworks modifying the landscape unfavourably	5
		Weak soil structure and texture	6
		Rockiness and stoniness (surface and sub-surface)	7
		Soil depth (restrictive)	8
		Depth to water table	9
AP	Animal Populations	Pressures by High Animal and/or Livestock Densities (e.g. decreased biomass, soil compaction, etc.)	1
		Surpassed animal carrying capacity of grasslands/rangelands/forests.	2
		Poor livestock and forage (grasses) diversity	3
		Invasion of excessive animal populations	4
		Habitat recession and disappearance	5
PP	Primary Productivity	Decline in Primary Production of Ecosystems	1
		Increased demands of forest products	2
		Recess of land cover area/increased exposure to erosive forces	3
		Increased demands of bio-energy	4
		Nutrient exports ("mining")	5
		Soil organic matter and Carbon depletion	6
PS	Personal safety	Conflict & violence (presence & frequency)	1
		Volatile political and rural policy system	2
FI	Food insecurity	Crop yield decreases in past 3 or more years	1
		Frequency of total crop failures	2
		Low value of production/unit area	3
		Increase in deficit of production of staple foodstuffs locally	4
		Low per capita calorie/protein intake	5
		% Malnourished (underweight) rural children under 5	6
WI	Water insecurity	Change in water availability per capita	1
		Increased distance to water supply & collection	2
		Increased time spent in collecting water	3
		Deterioration of water quality (increased turbidity and /or contamination)	4
		Low % of rural population with access to water	5
EI	Energy insecurity	Affordability and accessibility to main energy source (unfavourable to biomass)	1
		Changes in main energy source	2
		Main fuel sources	3
LO	Loss of opportunity	Migration (permanent/seasonal)	1
		Poverty gap index/income	2
		Land tenure constraints (type, access)	3
		Access to common cultivable land Ha/farmer	4
DC	Demographic changes	Population growth rate (higher demands on resources)	1
		Population density (high pressures on the land and resources)	2
		Age/gender distribution & occupation (unfavourable to land	3

CODE	DRIVING FORCES	PRESSURES	CODE
		stewardship and lack of involvement of women)	
		Aging farming population and increase in young landless people	4
		Migration of the young and /or poor participation in rural community affairs.	5
		Rural infant mortality rate (per 1000 live births)	6
		Change in non-farm employment	7
		Unemployment rate	8
LI	Level of investment	% National budget in rural and agricultural development	1
		Lack of personal investment in the land and land activities	2
		Lack or low government investment in land programs in rural areas.	3
		Low level of Government/institutional staff involvement in agricultural research and extension	4
		Research and investment focus on crops vs. resources	5
AC	Access	Credit availability (lack of)	1
		Presence/use of banking institutions (lack of)	2
		Access to markets of input & output supplies (distance, transportation, type)	3
LT	Land Tenure	Uncertainty of land tenure	1
		Unregulated, unrestricted use of common lands	2
LP	Land Policies	Tax exemptions i.e. for large-scale farms.	1
		Land tax or incentives for certain land use types of high intensity.	2
		Absence or non-enforced by-laws on land-use and protection	3
MA	Macro-economic policies	Legislation for natural resource management (absent or non-enforced)	1
		Globalisation, trade agreements and barriers unfavourable to small, self-sustaining (non-export) farmers, or limiting export/import opportunities to them.	2
		Manipulated rural investment policies and exchange rates to favour exports.	3
		Policies to reduce farm income volatility i.e. produce	4
		Price guarantees .	5
MI	Micro economic policies	Credit schemes favouring a certain produce	1
		Introduction of untested and unsuitable land use types	2
PR	Privatisation	Farmer groups/associations/co-operatives (absent or weak)	1
IS	Institutional support	Lack of knowledge of institutional frameworks and support	1
		Ignorance of regulatory frameworks	2
		Cumbersome requirements of institutions & bureaucracies	3
		Absence or weak natural resource institutions	4
TR	Transport	Density/type of road networks (unfavourable or poor)	1
		Availability/accessibility of public transport (lack of)	2
WA	Water	Lack of stream/storm/runoff control structures	1
		Water distribution system (adequacy or absence)	2
		Sewage/road runoff collection & treatment (adequacy)	3
SW	Solid Waste	Access to latrines	1
HO	Housing	Waste disposal type, location, proximity to population (absence or adequacy)	1
ED	Education/Skills/Knowledge	Low literacy rate and education	1
		Difficult access to schools	2
		Availability of extension services/agricultural education	3
		Availability of environmental education (lack)	4
CU	Culture	Lack of land stewardship	1
		Lack of livestock management culture	2
HE	Health	Lack of sexual /family planning education	1
		Days/year unable to work on land due to illness or poor health	2
		Indigenous technical knowledge of land management & resource extraction	3

(c) Integration of driving forces and pressures to states of land degradation from field assessment data

For the purpose of following the DPSIR approach the integration of driving forces and pressures to the states of land degradation, as determined from the indicator information obtained from field interviews, field forms and published data and information, is a relatively involved process. In the absence of an automated integration decision support system (conceptual at this stage), as described in section 6 and Figures 13 and 14 above, the comprehensive chart in Figure 10 above, which illustrates the linkages between the different components of the DPSIR approach, can be used for the purpose of achieving the integration. From this chart, a subset of the driving forces and pressures acting in the studied area can be derived. Such sub-set can be interpreted from the questionnaires, surveys and field forms and the interpretations organized in terms of networks of causal chains. These networks of causal chain can be derived through the use of the checklists in the forms described in the manual procedure illustrated in the diagram of Figure 16, above, again, in the absence of an automated "integration decision support system". Once an understanding of the driving forces at work in an area is attained from background written materials and interviews with farmers and other stake-holders in the area, the creation of these networks of causal changes becomes very intuitive and quite feasible for the average technician and practitioner.

Impacts and responses observed and obtained from field surveys and interviews should also be summarised both textually and graphically and reported, with specific reference to particular regions of the studied area, when applicable. Their graphical representation has been illustrated in Figure 18.

The physical data collected should be integrated and analysed by land facet or any other unit resulting form stratification of the environment. The indicator data from the field should be then interpreted through the DPSIR approach and the land degradation classification designed and suitably coded in a legend for mapping purposes, should be implemented. The state of degradation can then be reported with reference to the types of degradation, their extent and severity, together with each driving force and pressure acting on the resources of the land facet.

The ESCWA land degradation methodological framework is to be built and fine-tuned from pilot projects in participating countries. Therefore, for successful application of the framework a bottom-up approach is required, supporting stake-older participation through the 'auto-diagnosis' process, to avoid producing technical studies without practical follow-up or impact at national, sub-national and local levels. The final step in the application of the framework is the reporting of findings both, in terms the spatial distribution of types and intensity of land degradation as well as in terms of a concrete and succinct description of its causes (driving forces and pressures) as well as the impacts on the different livelihood sub-systems and the responses to those impacts by the stakeholders.

V. APPLICATION OF THE FRAMEWORK: LEBANON CASE STUDY

A. STUDY AREA COUNTRY DESCRIPTION

Lebanon has a total land area of 10 400 km² situated east of the Mediterranean Sea with 225 kilometres of coastline and extends 50 kilometres inland between Israel and Syria (CIA, 2004). Administratively Lebanon is divided into six Mohafazats (provinces). It is a country with limestone, iron-ore, and salt deposits, arable land and is a relatively water-rich state in a region with great water deficit. The following sections provide a brief description of the biophysical, socio-economic and human conditions of Lebanon and of the specific study area for mapping, delineated by the caza of El Hermel. These sections are not intended to be comprehensive; they are only to orient the reader to the situation of the study area. Refer to such works as The National Action Programme for Land Degradation for Lebanon (UNCCD/UNDP/GTZ, 2003) for a comprehensive country description.

1. *Biophysical conditions*

Lebanon has mountainous, rugged terrain, with the Mount-Lebanon and the Anti-Lebanon chains parallel to the sea, separated from each other by the Bekaa plain. Its geography and physiography determines its climatic conditions, which vary from Mediterranean climate along the coastal plain and in the middle mountain range and sub-alpine climate on the high slopes that are covered by snow during most of the year (CoDel, 2005).

(a) *Climate*

The influence of the Mediterranean Sea and the topographic features create microclimates within the country with contrasting temperatures and rainfall distribution. As in most Mediterranean climates, Lebanon's precipitation occurs between November and March, in the form of heavy rain showers. The remaining months of the year experience dry and arid conditions. The mean annual rainfall in coastal regions is between 700 and 1 000 mm; the central mountains receive up to 1 600 mm, and on the Bekaa plain rainfall ranges from 200 mm in the north-east to 800 mm in the south; while on the Anti-Lebanon chain it ranges from 600 mm to 1 000 mm (CoDel, 2005).

The coastal average annual temperature is 20°C, ranging from 13°C in winter to 27°C in summer; 16°C in the Bekaa valley, ranging from 5°C in winter to 26°C in summer; and less than 10°C at higher elevations in the mountain zones, ranging from 0°C in winter to 18°C in summer (FAO, 1997).

(b) *Water resources*

Lebanon has a relatively favourable position in terms of its rainfall and water resources, it is one of only four countries in the ESCWA region that doesn't rely on external water supplies (according to 1996 data presented by WANA/LARS, 1999). Of Lebanon's 10 400 square kilometres, 170 are covered with water (CIA, 2004). Being at a higher elevation than its neighbours, Lebanon has practically no incoming surface water flow, however, there are about 40 major streams in Lebanon, including the Nahr el Litani, the only major river in the Near East not crossing an international boundary (CIA, 2004).

Lebanon's annual internal renewable water resources are estimated at 4.8 km³. Annual surface runoff is estimated at 4.1 km³ and groundwater recharge at 3.2 km³, of which 2.5 km³ makes up the base flow of the rivers. Approximately 1 km³ of this flow is contributed by over 2 000 springs with about 10-15 l/s of average unit yield, sustaining flow for 17 of the major streams in the country (FAO, 1997).

The major constraining factor for water development is the inconsistency of water supply during the summer dry months. In fact, about 75% of the annual stream flow occurs in the five-month period from January to May, 16% during June and July and only 9% in the remaining five months (FAO, 1997). In addition, the manageable water resources of Lebanon are lower than the global average because of groundwater flow to the sea and the difficulties related to its control, and due to the limitations posed by the geological conditions for viable sites for storage dams (FAO, 1997).

Ground water is extracted by about 2 500 wells tapping the major regional aquifers. The depth of these wells varies between 50 to 300 metres. In 1994, water withdrawal for agricultural, domestic and industrial purposes was estimated at 1 300 million cubic metres, of which 67.7% was for agricultural purposes, 28.4% for domestic use and 3.9% for industrial use (FAO, 1997). Over-pumping from these wells is considered as the major reason for saltwater intrusion (Abdallah, 2002).

(c) *Geology, topography and soils*

Topographically, Lebanon is divided into four parallel units (see Figure 20) with a flat, narrow coastal plain less than 5 kilometres wide running parallel to the sea; the Lebanon Mountain chain rising to 3088 meters; the Bekaa Valley is 8-10 kilometres wide at an altitude of 900 metres; and the up to 2800 metre high Anti-Lebanon Mountain chain along the border with Syria (CIA, 2004; FAO, 1997).

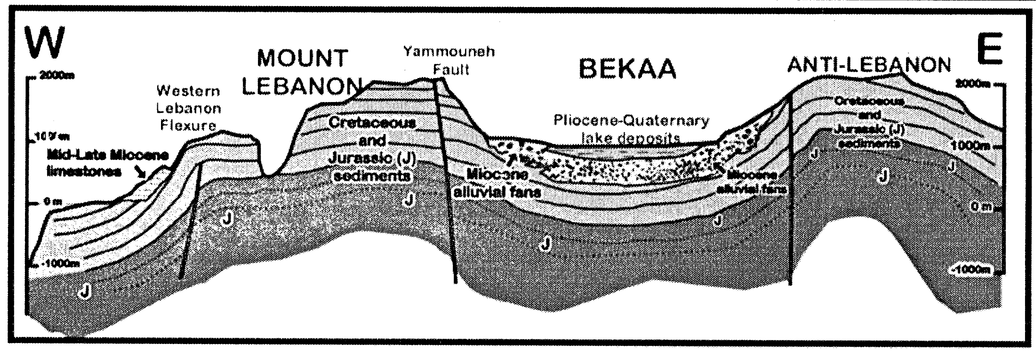


Figure 20. Schematic east-west cross section of Lebanon (UNCCD/UNDP/GTZ, 2003).

These topographical changes occur over a 60 kilometre horizontal distance, resulting in dramatic changes in relief and a range of intensity of land degrading processes such as landmass movements, sediment transport and erosion (UNCCD/UNDP/GTZ, 2003).

Lebanon is primarily comprised of carbonate rock (mostly limestone) that ranges in age from Middle Jurassic to Eocene. Other rock types with lesser presence include sandstones, basalts and

other much older volcanic materials, shale, conglomerates and unconsolidated deposits (UNCCD/UNDP/GTZ, 2003).
Lebanon's soils are typically less developed, young, poorly structured, shallow and susceptible to erosion by water and wind, resulting in some areas of bare rock.

In the semi-arid and dry-sub-humid areas of Lebanon where high intensity, short duration rainfalls are common, erosion is strongly lined to flash floods, which are "frequent, recurrent and widespread" according to Lebanon's National Action Programme to Combat Desertification (UNCCD/UNDP/GTZ, 2003). These processes are evident in the landforms and local topography where they have left marked land-scarring rills and gullies.

(d) *Land cover and land use*

Due to its physiographic and geographic features, Lebanon has a variety of microclimates, which support diverse populations of pant and animal species. There are an estimated 4200 species in the country, including 2600 plant species, 311 of which are endemic (UNCCD/UNDP/GTZ, 2003). Lebanon was once known for its forest stands, however years of intensive woodcutting and the expansion of agro-pastoral and urban land uses have left only patches of relic forest (about 70 000 ha, or 7% of land) and scrub vegetation.

Lebanon has favourable conditions for agricultural production, with a cultivable area of approximately 360 000 ha, or 35% of total land are (CIA, 2004). Total cultivated area during the period from 1992-94 was around 190 000 ha, of which approximately 55% was under annual crops and 45% under permanent crops consisting mostly of fruit trees and olives (FAO, 1997).

According to the 1970 census, there were 140 000 farm holdings, 63% of which having farms less than 2 ha in size. Reports from 1985 showed that about only 46% of farm holdings were less than 2ha (FAO, 1997) indicating a decline in the number of small farmers. Currently the agricultural land per capita in Lebanon is only 0.074 hectares (Sarraf *et al.*, 2004).

The total land area with potential for irrigation based on soil and water resources, is estimated at 177 500 ha. In 1993, the total area equipped for irrigation was estimated at 87 500 ha (FAO, 1997), consisting mainly of surface irrigation with sprinkler irrigation only being practiced on approximately 21 000 ha (FAO, 1997). During the period 1992-94 the main irrigated crops were fruit trees, vegetables, potatoes and, to a lesser extent, cereals (maize, wheat, barley) and sugar beet. The estimated average yield for irrigated wheat and barley was 5.0 tons/ha, compared to 2.2 tons/ha of rainfed wheat and barley (FAO, 1997)

2. *Demography*

(a) *Population and housing*

The population of Lebanon was estimated to be just over 3777000 in 2004, approximately 1 million of who are foreigners, and is growing annually at a rate of 1.3% (CoDel, 2003, CIA, 2004).

The average population density is reported at 420 people per square kilometre (Sarraf *et al.*, 2004), with about 88% of the population in urban areas. The growth rate is negative in rural areas due to the national migration towards Beirut and its suburbs (UNCCD/UNDP/GTZ, 2003).

Today Beirut is home to one-third of the population, and 800,000 more commute in every day (New Internationalist, 2004).

(b) *Institutional and legislative environment*

The purpose of this section is to provide a brief overview of the state of the institutional and legislative environment of Lebanon as they relate to land degradation. There are reports outlining in great detail the environmental laws and decrees in Lebanon (see MOE, 2001 or UNCCD/UNDP/GTZ, 2003). Thus, the following provides a summary of the most relevant issues.

Environmental management in Lebanon are governed by a number of ministerial decisions, laws and decrees. Most influential are those of the Ministry of Environment. Government agencies at the national and local levels are developing a Law (667/9, Article 3), which calls for establishing the National Environmental Council, which would be responsible for formulating proposals and recommendations for environmental policy and for suggesting implementation plans that would be binding upon their approval by the Council of Ministers. Membership to the Council is to be divided among representatives of concerned ministries and those of civil society (NGOs, private sector, academia). However, to date, the Council is still not in place (UNCCD/UNDP/GTZ, 2003). The most relevant Lebanese laws and decrees related to land degradation are summarised in the following table (Table 9).

Table 9. Relevant legislation concerning land degradation in Lebanon (UNCCD/UNDP/GTZ, 2003)

RESOURCE	ARTICLE	DESCRIPTION
Land and Soil	Articles 8 & 7 of law decree 69, 6/9/1983 (referred to as the Code of Urbanism)	A detailed urban plan should determine "the lands to be protected for agricultural use"
	The law promulgated on 9/11/1951	Grants Ministry of Agriculture authority to implement reforestation policy as initiative for soil protection
	Ottoman Medjelle article 1234	Provides that herbs in a common land are for all.
Pesticides	Decree 10659 dated 21/9/1970	Specifies legal conditions to produce and sell pesticides, control their production and distribution with a view of protecting the environment and human health
Natural Sites & Monuments	Decree 434 promulgated on 28/3/1942	Listed eight sites to be protected (more added during the 1990s)
	Law 121 dated 9/3/1992	Introduced concept of protected areas in Horch Ehden and Palm Island.
	law 532, 24/7/1996; law 718, 5/11/1998; law 9, 20/2/1999; law 11, 20/2/1999	Cedar in the Chouf area; Natural marine reserve in Ras el Ain – Tyr; Cedars forest of Tannourine; protected area in Bentael (respectively)
	Law no. 19, October 20th, 1990	Allowed the ratification of the UNESCO Convention for protection of world cultural and natural heritage
	Decrees 19/1, 22/1, 21/1, 11/3/2002	Declare Kammoua, Dalhoun forest and Wadi al Karakir respectively as natural sites for protection
Forests	The forest law, January 7, 1949	Organizes protection and utilization of forests. 151 articles detailing general conditions and specifying what constitutes a forest and the manner of managing them. Article 2 of the forest law divides forests into four types: State-owned forests; State-

	11/3/2002	Karakir respectively as natural sites for protection
Forests	The forest law, January 7, 1949	Organizes protection and utilization of forests. 151 articles detailing general conditions and specifying what constitutes a forest and the manner of managing them. Article 2 of the forest law divides forests into four types: State-owned forests; State-owned which give villages the right of utilization; Municipality and village-owned forests; and Forests owned by individuals. The law laid down various penalties (fines or imprisonment from three to six months) for offences perpetrated by individuals.
	Law 558; 24/7/1996	Provides a legal framework for the protection of forests
Water	Decree 144, 10 June 1925 Decree 320, 26 May 1926	The first relates to the public domain. Constitute the fundamental texts governing water in Lebanon. Undergone minor amendments but original principles have not been altered
	Ottoman Irrigation Code, 11 February 1913	Relates to the arrangement and the renovation of common irrigation canals.
	Law No. 320, May 26, 1926; Decree 14438, May 2, 1970; Decree 10276; Legislative decree No. 112, December 16, 1983; No. 680, September 5, 1990; Law No. 221, May 29, 2000; Law No. 241, August 7, 2000; Law No. 377, December 14, 2001; Decree No 8122, July 3, 2002	At the same time as the above laws, a series of decrees were progressively created to regulate some sectors of water law. General principle concerning water resources is that title belongs to the State by virtue of its control of "the public domain"
Groundwater	Art. 6 of Decree 320/26 and Decree 14438, 2 May 1970	Use of groundwater, the latter decree regulates the granting/exemption of prospecting permit
Quarries	Decree 8803, 4/10/2002	To enhance enforcement and establish the formal conditions to obtain a permit for the exploitation of a quarry.
	Decision 2, 77th session of the council of Ministers	Amendments made to localization of quarries in the eastern mountain chain and mandatory rehabilitation of quarried sites at the expenses of the owners by terracing and replanting.
Code of the Environment	Law 444, August 8, 2002.	

Table 9. Relevant Laws, Decrees and Decisions related to land degradation in Lebanon (UNCCD/UNDP/GTZ, 2003)

Other ministries and authorities related to environmental resources and land degradation are described below. The Ministry of Hydraulic and Electrical Resources (MHER) manage irrigation and water resources development. Under its responsibility is the Litani River Authority (LRA), in charge of implementing irrigation projects in South Bekaa and Southern Lebanon, and of exploiting the potential Qasmieh - Ras El Ain coastal irrigation scheme. Twenty-five local irrigation authorities are also under the responsibility of MHER and 126 local irrigation committees, which were instituted by Ministerial Decrees during the period 1984-1990. There is an institutional plan to merge these authorities and committees into five main authorities, at the Mohafazat, or provincial, level (excluding Beirut) (FAO, 1997).

Agricultural development is the responsibility of the Ministry of Agriculture (MOA) and, under its responsibility, the Agricultural Research Institute (IRAL) and the Green Plan (GP). The GP have been given autonomy, with responsibility for land preservation and reclamation, rural roads construction, small hydraulic development of hillside stock ponds and farm-level infrastructure works. In addition, the MOA established an autonomous institution, 'The Institution for Alternate Crops', centring on the Baalbeck-Hermel traditional region of illicit crops.

Water laws and regulations on water are mostly outdated and water rights constitute a constant source of disputes. Groundwater is extracted by thousands of informal private wells with no licences, water metering or charges or taxes (FAO, 1997). In 1997, many water resources planning studies were under way by CDR, MHER and LRA. The most important decree for regional water resources planning is Decree No 14522 (10 May 1970), which organizes the allocation of available water resources south of the Beirut River to the southern international borders and up to the 800 metres elevation on the western skirts (FAO, 1997).

The main issues contributing to the problems of environmental protection in Lebanon are unclear definitions of roles of partners in environmental protection, a lack of coordination of goals with the private sector and problems with enforcement. The roles of the various ministries and government institutions involved in environmental protection are not clearly defined, resulting in overlapping areas of responsibility, inefficiency and in some cases conflict. Legislation tends to be reactive and only enacted out of necessity and there is a lack of coordination between public and the private sector (UNCCD/UNDP/GTZ, 2003). Environmental enforcement remains a major weakness of the environmental control system. The causes are identified as a lack of clarity and internal inconsistencies in legal and regulatory texts, and from institutional weaknesses, special interests, and political interference that stand in the way of effective enforcement. MoIM's police agents are often responsible for enforcing legal requirements developed by other ministries, the result is that ministries cannot directly enforce the legal requirements falling under their jurisdiction. Generally, a stronger adherence to legal requirements has been observed when the Lebanese Army has been in charge of enforcement (MOE, 2001).

3. *Economic Setting*

The civil war that stretched from 1975 to 1991 left Lebanon in economic crisis, with damaged infrastructure and low national outputs. Infrastructural loss were estimated at $25-$30 billion US. Widespread high inflation occurred between the mid 1980s and 1992, which added dramatically to the impoverishment of a fragile population (UNCCD/UNDP/GTZ, 2003).

Human displacement during and following the war has distorted the population pyramid in many regions. Statistics from the UNDP report that during the war half a million people were displaced and about 900 000 left the country, the majority of these emigrants were young people, mostly males between 20 and 25 years of age (UNCCD/UNDP/GTZ, 2003).

Lebanon is still struggling to recover economically from the war. The period between 1990 and 1992 witnessed enormous economic growth in Lebanon. Industrial exports increased from $190 million to $420 million, production of electricity increased from 1,394 to 4,033 million kilowatts, construction permits increased from 2,180 to 10,745, the number of passengers passing through Beirut airport increased from 709,000 to 1,043,000, the number of ships coming to Beirut's port increased from 671 to 3,054 (New Internationalist, 1994).

However, this growth has slowed considerably in recent years. Since the 1993 launch of "Horizon 2000," the government's $20 billion reconstruction program, GDP grew 8% in 1994 7% in 1995, 4% in 1996 and 1997, 1.2% in 1998, -1.6% in 1999, -0.6% in 2000, 0.8% in 2001, 1.5% in 2002, and 3% in 2003 (New Internationalist, 1994). In the year 2000 the GDP by sector included 12% agriculture, 21% industry, and 67% services. The unemployment rate was approximately 18% in 1997 (CIA, 2004) compared to 5.5% before the war and 35% in 1994 (New Internationalist, 1994). In 1999, 28% of the population were reportedly living below the poverty line (estimate provided in CIA, 2004) mostly in the rural cazas. Great disparity has been noted between regions in terms of poverty levels and infrastructure and services available (UNCCD/UNDP/GTZ, 2003).

The labour force involved in agricultural production declined from 25 % in 1967 to less than 9% in 1990. However, agriculture remains a vital source of income in rural areas. The number of full-time farmers is difficult to estimate, but most rural families have agriculture as at least a part-time activity and seasonal labour represents between 30 and 40% of the present agricultural labour force (FAO, 1997).

Today the main industries of Lebanon include banking, food processing, jewellery production, cement, textiles, mineral and chemical products, wood and furniture products, oil refining, and metal fabricating. Agricultural products include citrus, grapes, tomatoes, apples, vegetables, potatoes, olives, tobacco, sheep and goats. Export commodities include authentic jewellery, inorganic chemicals, miscellaneous consumer goods, fruit, tobacco, construction minerals, electric power machinery and switchgear, textile fibres and paper (CIA, 2004).

Much of Lebanon's physical and financial infrastructure damaged in the war has been rebuilt, relying heavily on capital borrowed mostly from national banks. To control the national debt, the government began a strict economic program to cut government expenditures, increase revenue collection, and privatize state enterprises (CIA, 2004).

4. Reported State of Land Degradation in Lebanon (UNCCD)

Lebanon is reported to be experiencing a range of degradation processes, caused by a combination of the natural environment and anthropogenic forces. Once known for its dense forests, Lebanon now has only sparse relic forest stands. Many species, both aquatic and terrestrial have disappeared or are endangered because of a variety of threats to their habitats.

A report for the UNCCD states that natural pressures include the steep topography of the country, the climatic variability in terms of the regional and seasonal distribution of rainfall, high intensity rainfall and flash floods, forest fires in the dry season and the calcareous, fragile nature of the soils (UNCCD/UNDP/GTZ, 2003). The combined effects of the relief, rainfall intensity and runoff quality, especially where the vegetation cover is reduced or lost, lead to significant soil erosion, mainly by water.

The anthropogenic causes of land degradation in Lebanon are caused mainly by unsuitable agricultural practices, deforestation and urbanization. Detrimental agricultural practices include the cultivation of fragile soils, use of poor and inefficient irrigation practices, excessive use of chemical products and the overgrazing of shrubs and grasses. Deforestation and exploitation of woody resources result from logging, collection of fuelwood, charcoal production, grazing (particularly damaging in the slow growing coniferous forests), quarrying (690 quarries in

Lebanon are causing a loss of vegetation cover and an increased tendency for slope failure, landslides, soil and gulley erosion) and the uncontrolled use of fire for land clearing (1200 ha of natural forests are burned each year). Rampant urbanization, particularly around Beirut, has lead to the loss of fertile lands to urban areas which forces farmers onto less suitable lands, and to rural farm abandonment, which has resulted in increased erosion on abandoned fields, the pollution levels, in all forms, are also adversely affected as the population increases (UNCCD/UNDP/GTZ, 2003). The years of war in Lebanon had an adverse effect on environments in Lebanon, due to pollution, soil compaction, and land abandonment and by enhancing poverty, mainly in remote rural areas. The agriculture sector's contribution to the GNP was significantly curtailed during and following the war. The driving forces of land degradation are described in the NAP document (UNCCD/UNDP/GTZ, 2003), and can be summarized in the following table (Table 10).

LEVEL	DRIVING FORCES & CAUSES
Local	Poverty and lack of basic security, lack of awareness, unsustainable land use practices, inadequate extension service, lack of technical know-how; absence of agricultural credit schemes
National	Civil war (1975-1990) and its consequences including displacement, migration and lack of enforcement of regulations, the absence of a comprehensive strategy for the sustainable use of natural resources, land fragmentation due to inheritance laws and the high transactional costs, a disabling land tenure system, an absence of land use planning and of policies and plans for water and agriculture
Institutional	The system of centralized decision-making, application of sectoral solutions for multidisciplinary problems, the weak inter-departmental and inter-ministerial coordination and cooperation, duplication of efforts, and overlap in the mandate of public institutions, the absence of regional structures for comprehensive natural resource management, and weak institutions at the local level
Legislative	Absence of a comprehensive legislative framework leading to reactive and inadequate legislation and the weak enforcement of existing legislation
Macro-economic	Foreign debt, unfavourable terms of trade, and unfair competition from subsidized imports

Table 10. The driving forces of land degradation in Lebanon (UNCCD/UNDP/GTZ, 2003).

B. THE CASE STUDY AREA

One area most severely affected by land degradation and desertification is El-Hermel, part of the Bekaa Valley. The caza of Hermel was selected as the case study area to apply the land degradation assessment procedure described in the previous chapter. This particular caza was selected for study because of the degree of impact felt by land degradation, in that it is an area dependent on agricultural production that has unfavourable climatic conditions and is experiencing processes of land degradation with high rates of poverty. It seems to represent a range of environments of the country, covering high plains, mountain slopes/hills and upland plains and is representative of the land degradation problems in Lebanon.

The Bekaa Valley is part of the study area. It is situated parallel to the coastline, separated from it by the Mount-Lebanon range, whose eastern flank is also part of the Caza Hermel and the study area, and it is flanked to the east by the Anti-Lebanon Range. The position of the study area is illustrated in the map of Figure 21. The rugged and contrasting terrain and the range of topography and geomorphologic conditions in the Caza Hermel study area can be appreciated in the satellite images in Figures 22 a-d, made using NASA World Wind (NASA, 2004) and in the map of topographic features and slope classes in Figure 23.

The geology of the Hermel study area, like in the rest of Lebanon, is primarily comprised of carbonate rock (mostly limestone) that ranges in age from Middle Jurassic to Eocene. Other rock types with lesser presence include basalts and volcanic materials at the top of the mountains in the western fringe of the area, and in the northeastern portion of the area, in the plains, there are sandstones, shale, conglomerates and unconsolidated deposits (UNCCD/UNDP/GTZ, 2003). The spatial distribution of geological materials in the study area is depicted in the map of Figure 24.

The soils in the study area are relatively young and undeveloped, derived essentially from alluvial and fluvial processes and depositions. Major soil associations in terms of spatial extent in the study area are Lithic Leptosols, Haplic Luvisols, Leptic Luvisols and Calcic Fluvisols. These soils are essentially in the highland plateau and at the based of the plateau consisting of a highly eroded inclines and torrential drainage landforms towards the Bekaa plain. Lesser abundant are Haplic Luvisols located at higher elevations and mountain tops to the south west of the area, while associations of Cambisols (Calcic and Eutric), Calcisols (Pelic and Eutric) and saline Solonchacks (Calcic) are present in the alluvial fans of the Bekaa valley and the flatlands to the east of the area joining the river banks. The spatial distribution of soils is shown in the map of Figure 25.

Half of monitored sites in Qaa, Hermel are in the range of slightly saline and saline soils, according to a study of open fields in the area conducted by Khatib et al. (1998) reported by UNCCD/UNDP/GTZ (2003). The results are typically a decline in yield and reduction in the number of suitable crops, as they are limited to salt tolerant crops.

Although most of the Hermel study area consists of a dry sub-humid and semi-arid environment, particularly in the low laying areas in the Bekaa valley (Figure 26), Hermel is considered a high risk area for degradation, with 16.5 percent of its land classified as at very high risk for degradation, 60.6% high risk, 19.0% moderate risk, 0.5% low risk and 3.4% urban areas (UNCCD/UNDP/GTZ, 2003). The aridity zones were calculated using P/PET, as described in Chapter 2, using data from FAO/AGROMET (2004). The major threats in the North Bekaa region contributing to land degradation include drought, wind and water erosion, flash floods, improper water management, overexploitation of groundwater resources, overgrazing, quarrying, unsustainable agricultural practices, unplanned urban sprawl, poverty and limited off-farm opportunities.

Ecologically speaking the Hermel study area comprises three main ecological zones: Wet upland mountains higher than 800 m.a.s.l. Dry hills that correspond to an upland "plateau" landform, and arid upland plains in the Bekaa valley (Figure 27). These ecological zones are very distinctive and can be identified in the landscape readily through their altitudinal floors and their landforms. The region suffers from long periods of moisture deficit and drought and periods of rainfall events with high intensity causing severe water erosion and flash floods causing damage to infrastructure and in some cases casualties (UNCCD/UNDP/GTZ, 2003).

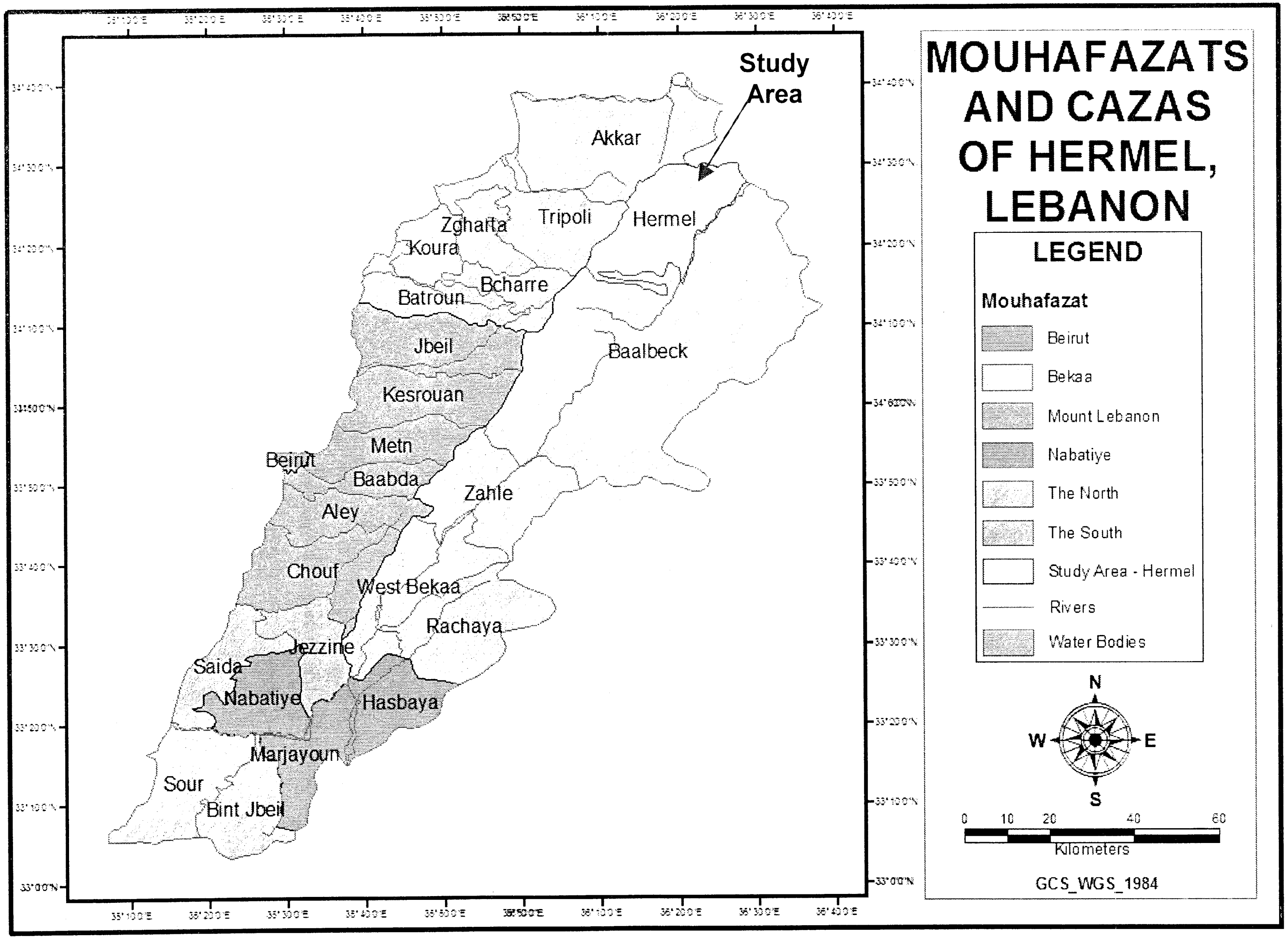


Figure 21. Location of the Caza Hermel Study Area in the Baalbeck Mouhafazat of Lebanon (CIP, 2004).

Fig 22a. **The Caza Hermel Study Area, Lebanon**

Fig 22b. **The Caza Hermel Study Area, Lebanon**

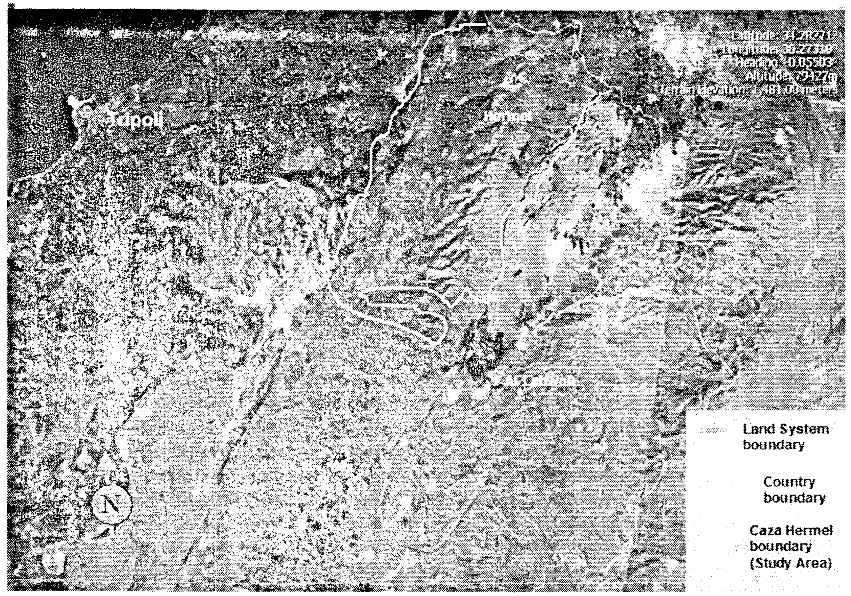
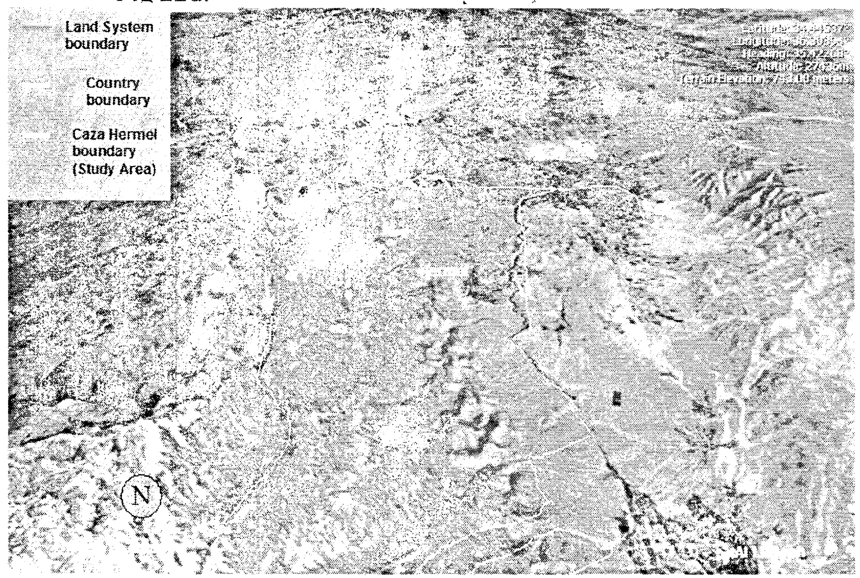


Fig 22c **The Caza Hermel Study Area, Lebanon**

Fig 22d. **The Caza Hermel Study Area, Lebanon**



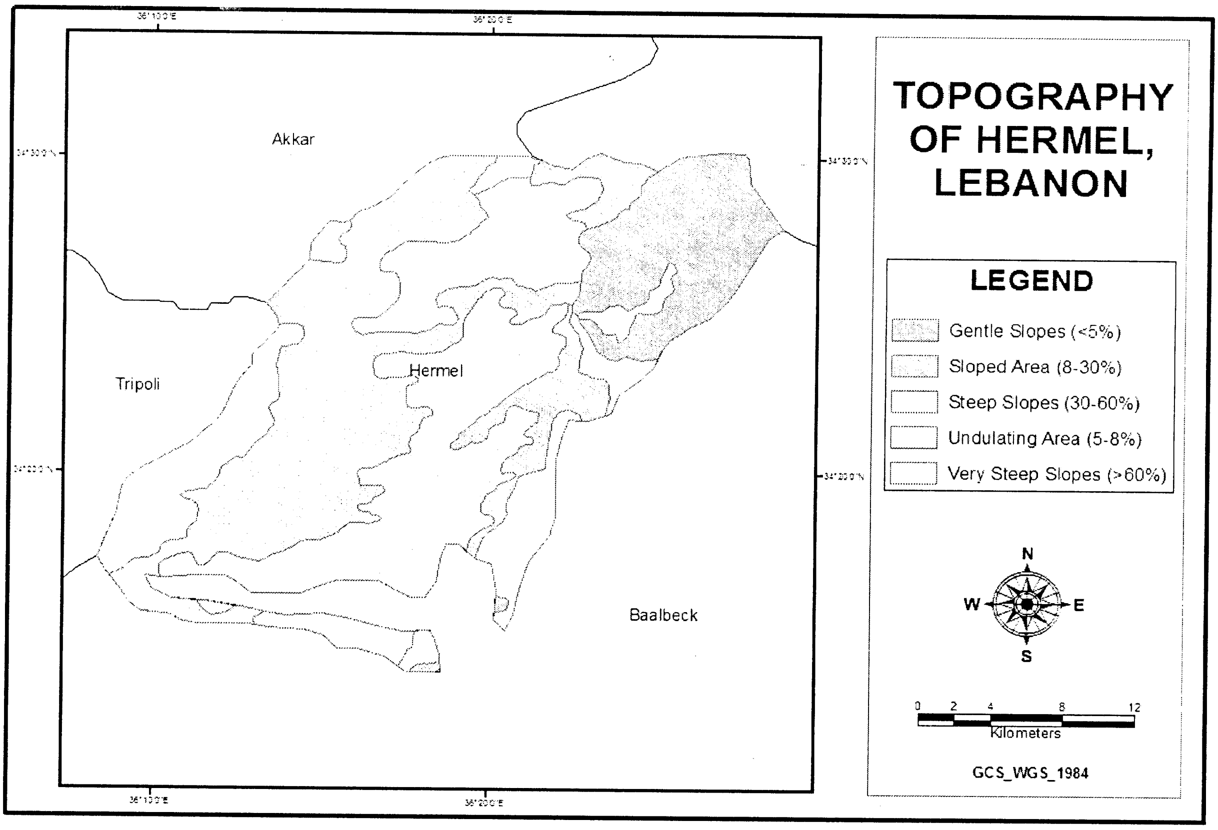


Figure 23. Topography and slope classes of the Hermel study area in Lebanon (produced from UNCCD/UNDP/GTZ, 2003).

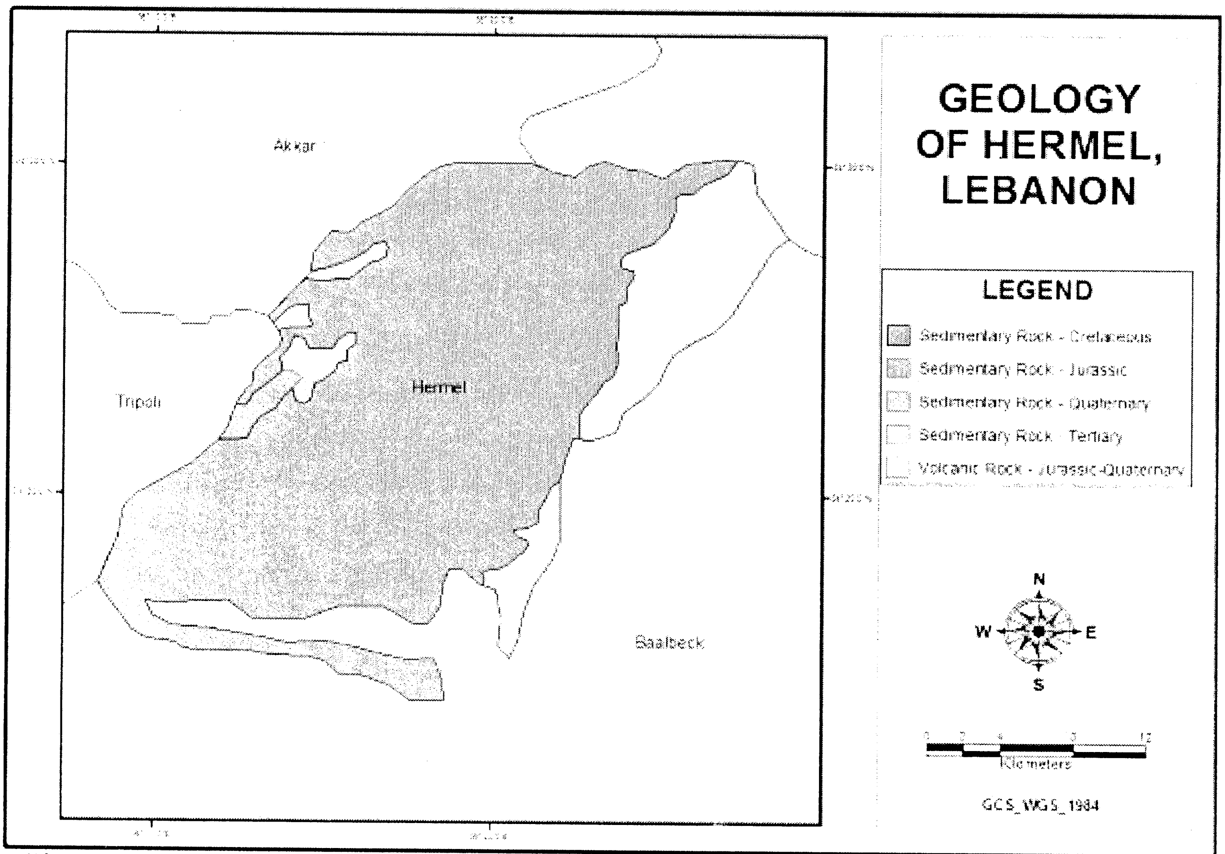


Figure 24. Surface Geology of the Hermel study area in Lebanon (produced from UNCCD/UNDP/GTZ, 2003).

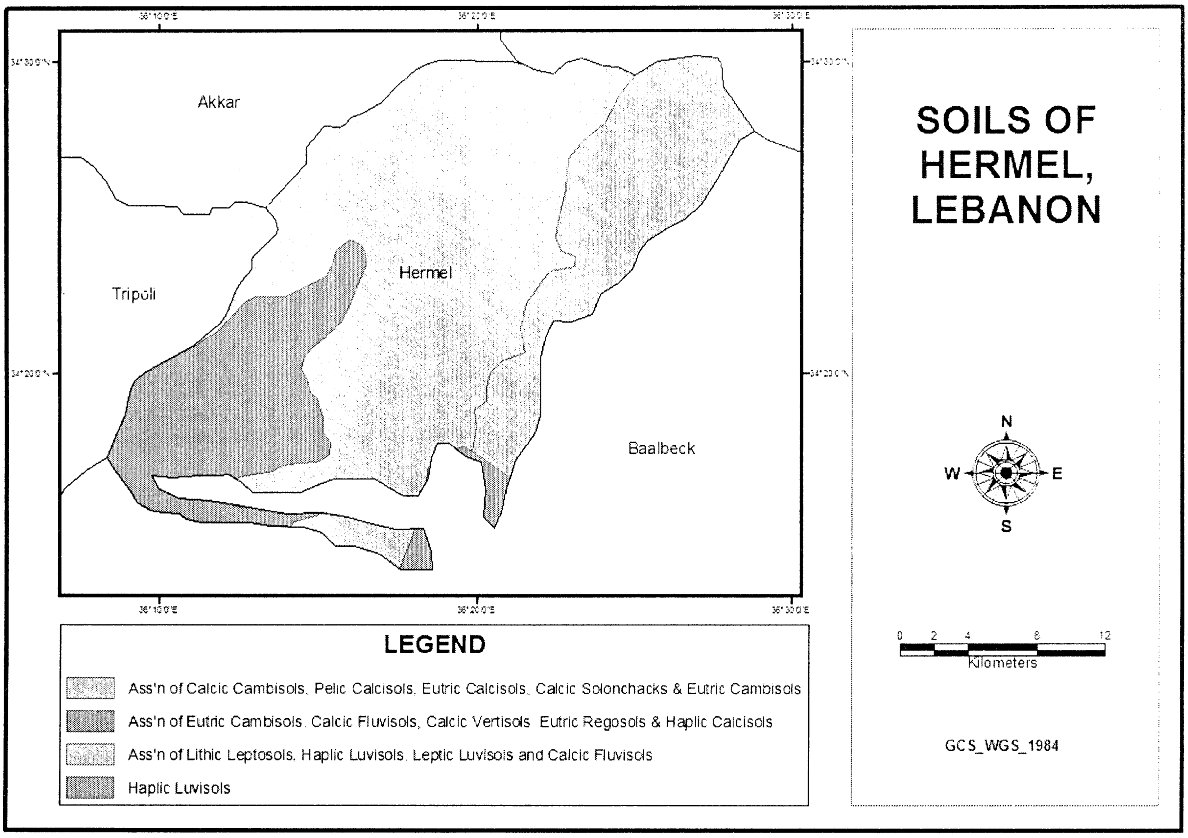


Figure 25. Soil orders and soil associations of the Hermel study area, Lebanon (produced from UNCCD/UNDP/GTZ, 2003).

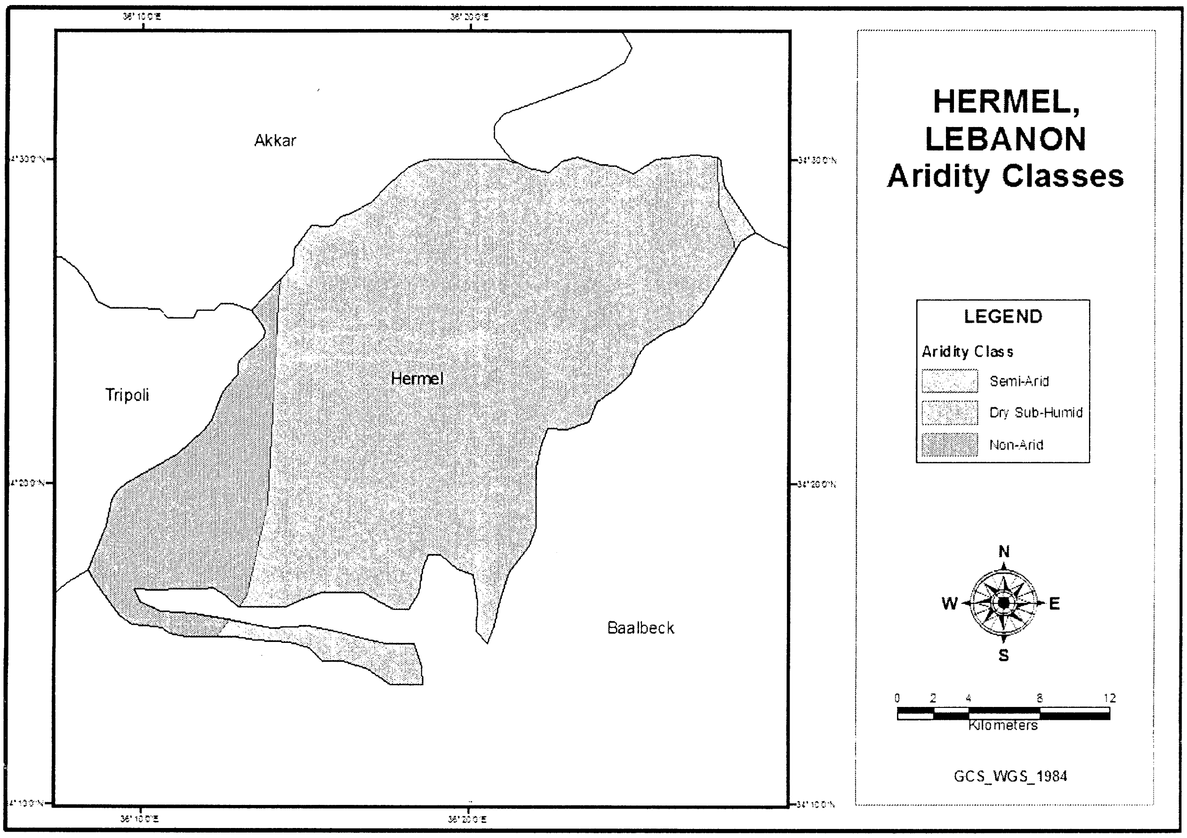


Figure 26. Aridity distribution in the Hermel study area in Lebanon.

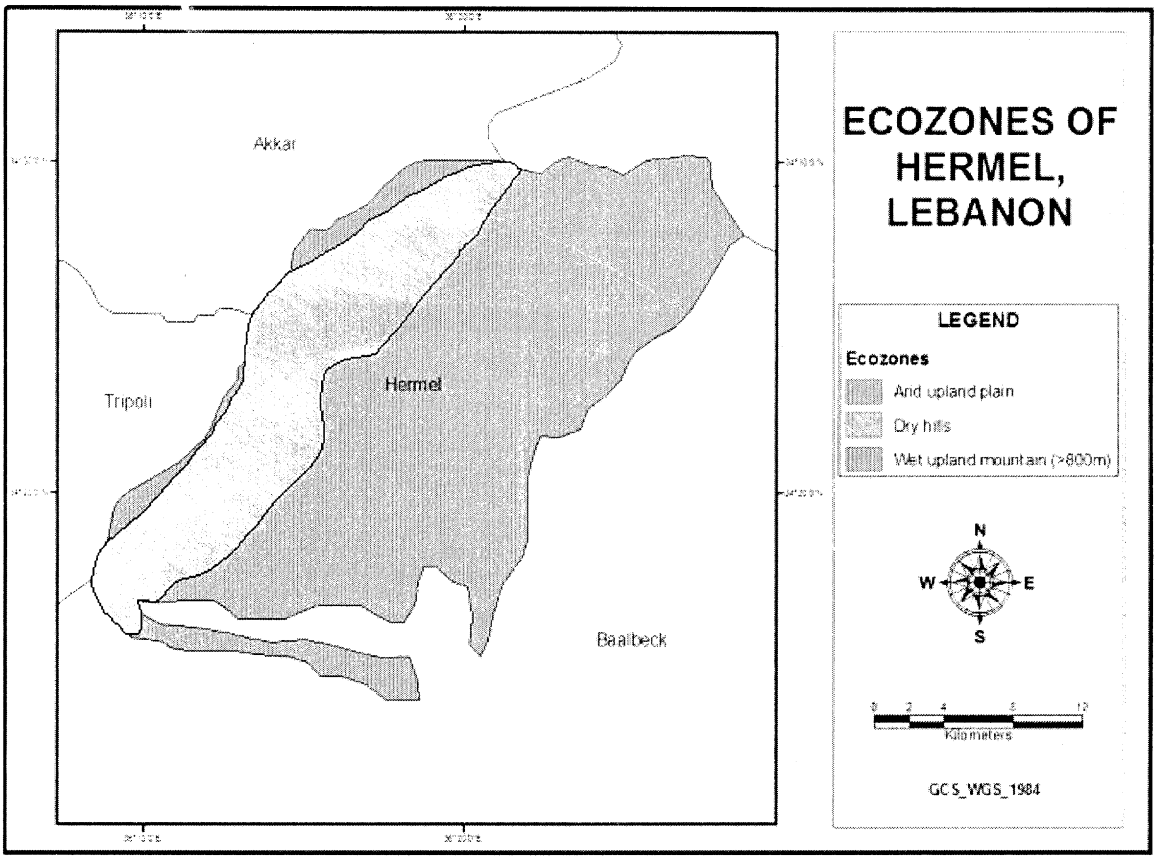


Figure 27. Ecozones of the Hermel case study area in Lebanon (MoA, 2003).

The land cover in Hermel consists mainly of semi-desert shrubs and a low sparse grassland and cold grassland at higher elevations. However, a predominant feature of this landscape is that it is denude of vegetation. There are only a few relics of forest and the landscape is punctuated by a small irrigated crop areas and grasslands (Figures 28 and 29).

The North Bekaa is predominantly an agricultural area, with few urban areas. The main sources of income are agriculture, commerce and, to a lesser extent, construction and enrolment in the army. It is reported that 24,000 families are involved in agriculture, using (in 1997) about 64,800 ha of which 37,800 ha were rain-fed and 27,000 irrigated. The total population of the North Bekaa is estimated to be around 250,000, which is scattered and may have up to 50% non-residents who have immigrated nationally or abroad in search of livelihoods (UNCCD/UNDP/GTZ, 2003).

The main agricultural products in Hermel are (in order of cultivated area) cereals, fruits, olives, industrial crops and vegetables (UNCCD/UNDP/GTZ, 2003). During the civil war the growing of illicit crops was a major source of income. In the early 1990's there was a massive eradication campaign, which caused great hardship and resentment. The crops have shifted to a range of traditional crops, including wheat, potatoes, tomatoes and watermelons. However, these crops are vulnerable to the fluctuations of the market and often do not provide enough income to satisfy the basic needs of farmers (UNCCD/UNDP/GTZ, 2003).

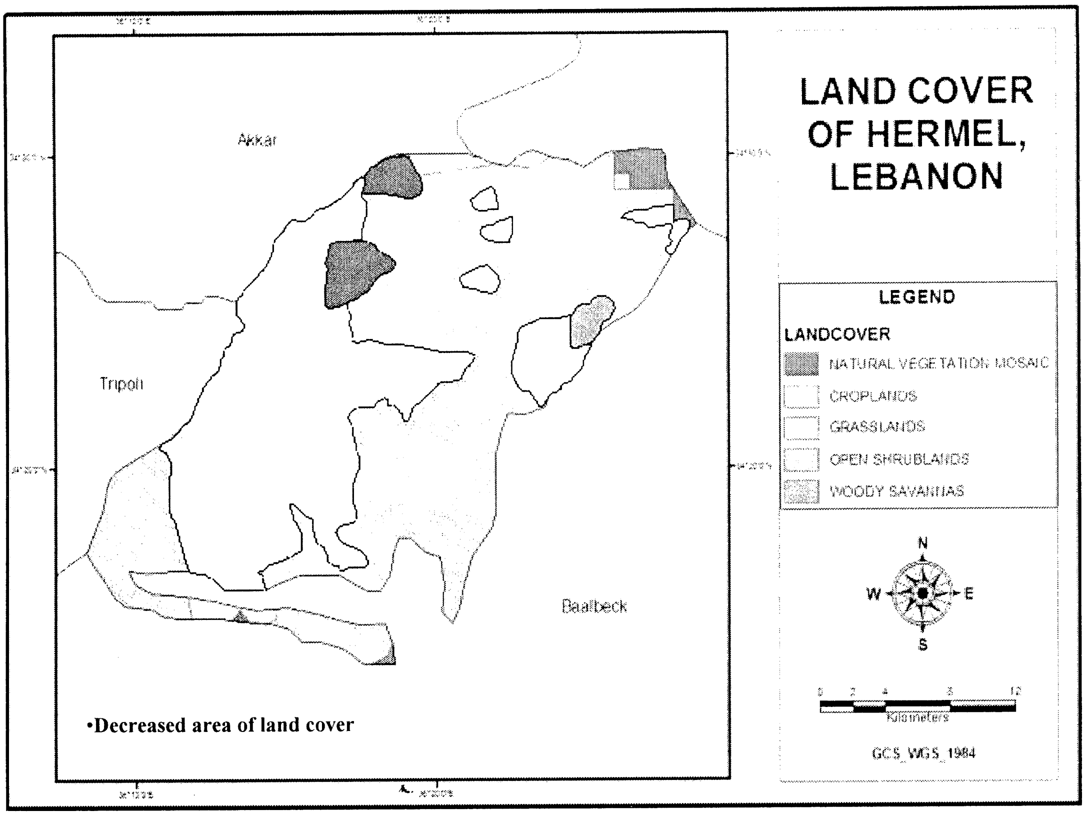


Figure 28. Land cover of the Hermel study area, Lebanon (UNEP, 2002).

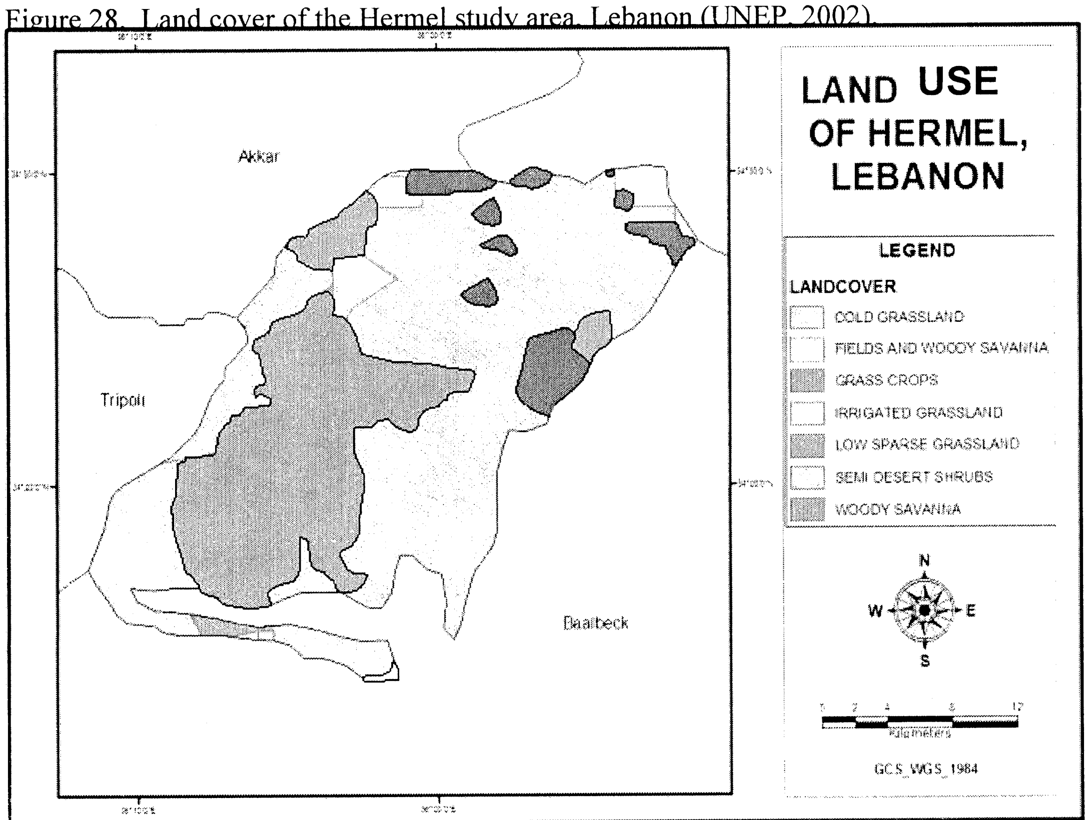


Figure 29. Land Use/land cover classes of the Hermel study area in Lebanon (UNEP, 2002).

Hermel is classified as a deprived Caza, and reportedly has the second lowest level of needs satisfaction, with 65.9 percent of households in Hemel below the threshold of the index of basic needs satisfaction (Table 11).

Caza	Average household size	School enrollment ratio (6-12 years) %	Illiteracy rate (10 years and above), %	Age dependency ratio (%)
Akkar	5.95	83.5	30.5	86.6
El-Minieh	5.69	85.0	24.8	70.5
Marjaayoun	4.50	90.1	23.6	67.5
Hermel	5.77	86.7	23.2	68.8
Bent-Jbeil	4.54	91.4	19.6	71.3
Baalbeck	5.26	90.7	18.3	68.9
Tyre	5.07	89.2	16.6	67.1
All Lebanon	4.55	88.9	13.6	56.8
Kesrouan	3.96	90.1	7.9	43.7

Table 11. Characteristics of the most deprived cazas compared to the average (UNCCD/UNDP/GTZ, 2003, citing MOSA and UNDP, 1998)

*Age dependency ratio refers to the percentage of persons in the ages defined as dependent (under 15 and over 65 years old) to those in the ages defined as economically productive (15 to under 65 years) in the population.

Another issue contributing to the economic insecurity and lack of development in the agricultural sector is the traditional inheritance laws, which have left heavy land fragmentation. Almost 50% households own less than 1 ha of land and only 11% own more than 5ha (UNCCD/UNDP/GTZ, 2003).

The lack of economic security and the period of civil war have resulted in a high rate of land abandonment. Figure 30 illustrates the amount of land in use and abandoned in Hermel.

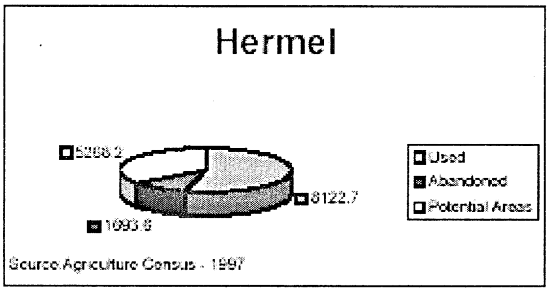


Figure 30. Agricultural land used, abandoned and areas with potential (UNCCD/UNDP/GTZ, 2003).

According to the NAP (UNCCD/UNDP/GTZ, 2003) the actions needed at the local level include:

- Resolving land tenure issues, as an essential prerequisite for sustainable agricultural and economic activities;
- Organizing groundwater use and implementation of water harvesting schemes;
- Efficient exploitation of the Assi river with proper irrigation schemes and water distribution networks;
- Regional rural development to alleviate poverty and create sustainable livelihoods;
- Promotion of profitable farming systems taking into consideration the sustainable use of natural resources;
- Promotion of sustainable agriculture practices including proper water, fertilizer and pesticide use;
- Rangeland management in order to promote soil and water conservation and to provide adequate feed resources for animal production
- Establishment of industrial zones.

C. RESULTS FROM THE ASSESSMENT OF LAND DEGRADATION IN THE HERMEL AREA

1. *Zoning and stratification of variability*

Following the methodological steps and the 12 core sets of activities as suggested by the framework, a stratification of the Caza Hermel area was achieved following a landscape approach (Ponce-Hernandez, 2004; Dixon, 2003). The ecological variability of the area was partitioned in terms of Land Systems and Land Facets. The boundaries identified for Land Systems coincide, to a large extent, with those of thematic maps of topography, ecological zones, geology, soils and land cover in the area, indicating therefore their pertinence and convenience. These boundaries were mapped out in colour composites of satellite images, both on the plane (flat) and through perspectives of three-dimensional (3-D) digital representations of the terrain. The results of the stratification yielded two Land Systems, namely: Land System "Yamouneh Plateau" and "Land System "Bekaa Valley". These units can be observed in the sequence of plates in Figures 31, 32a-b and 33a-b. The component Land Facets of each Land System resulted in areas of simple landforms with uniformity in moisture, rock, soils, moisture regime and land cover such that they can be given similar management throughout.

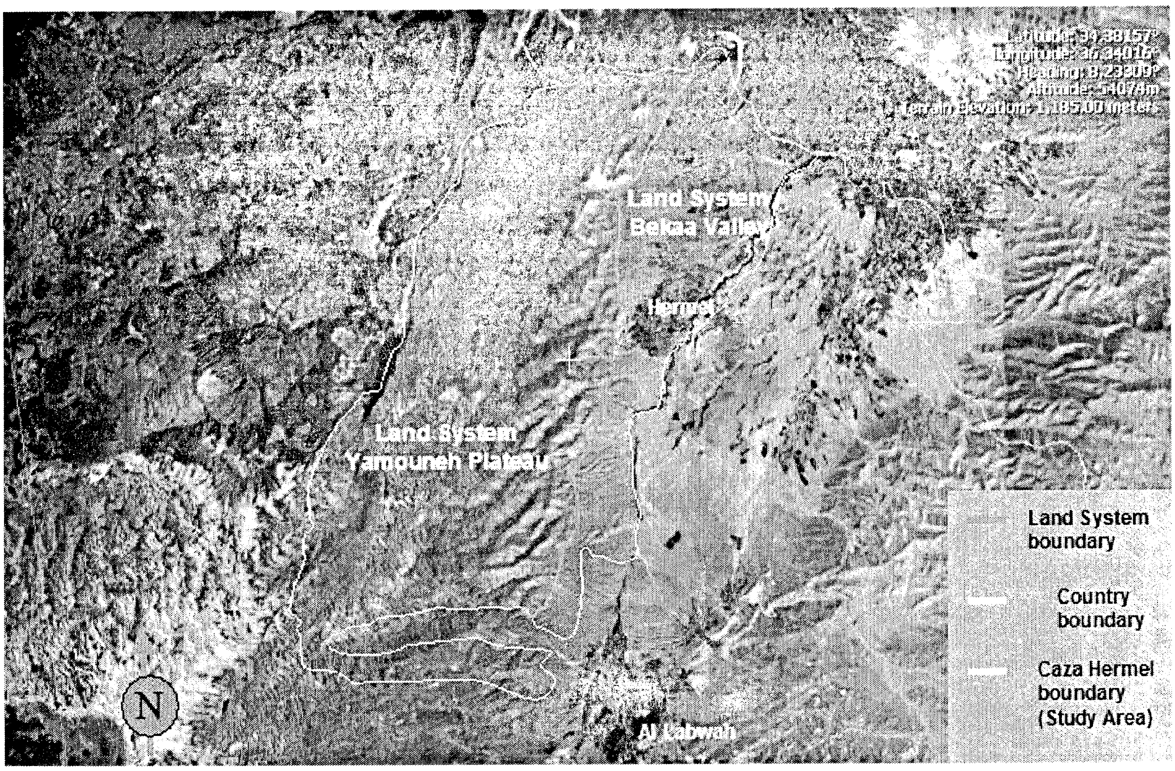
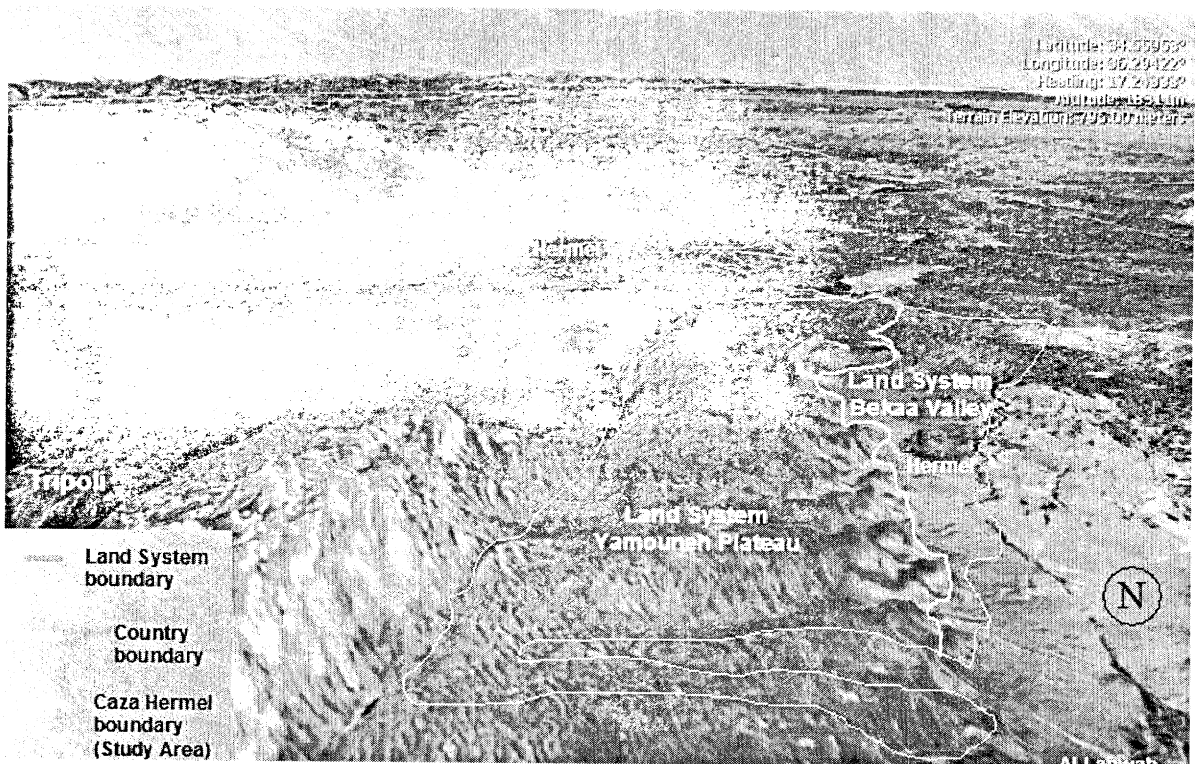
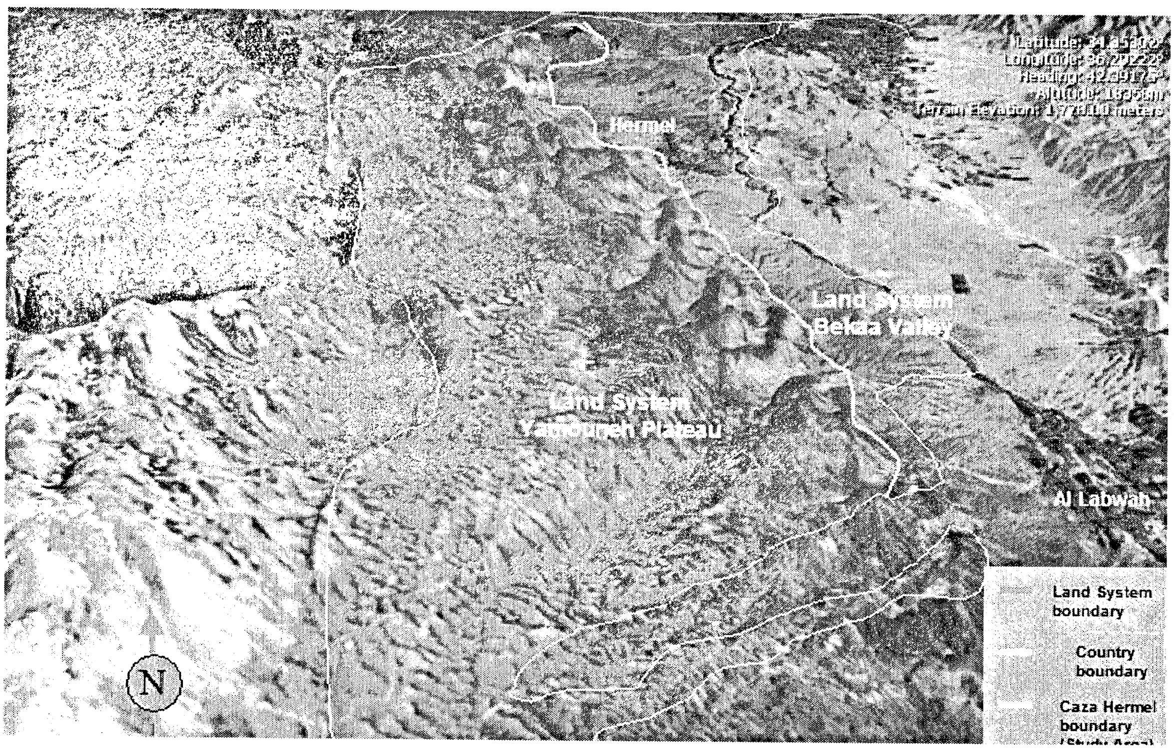
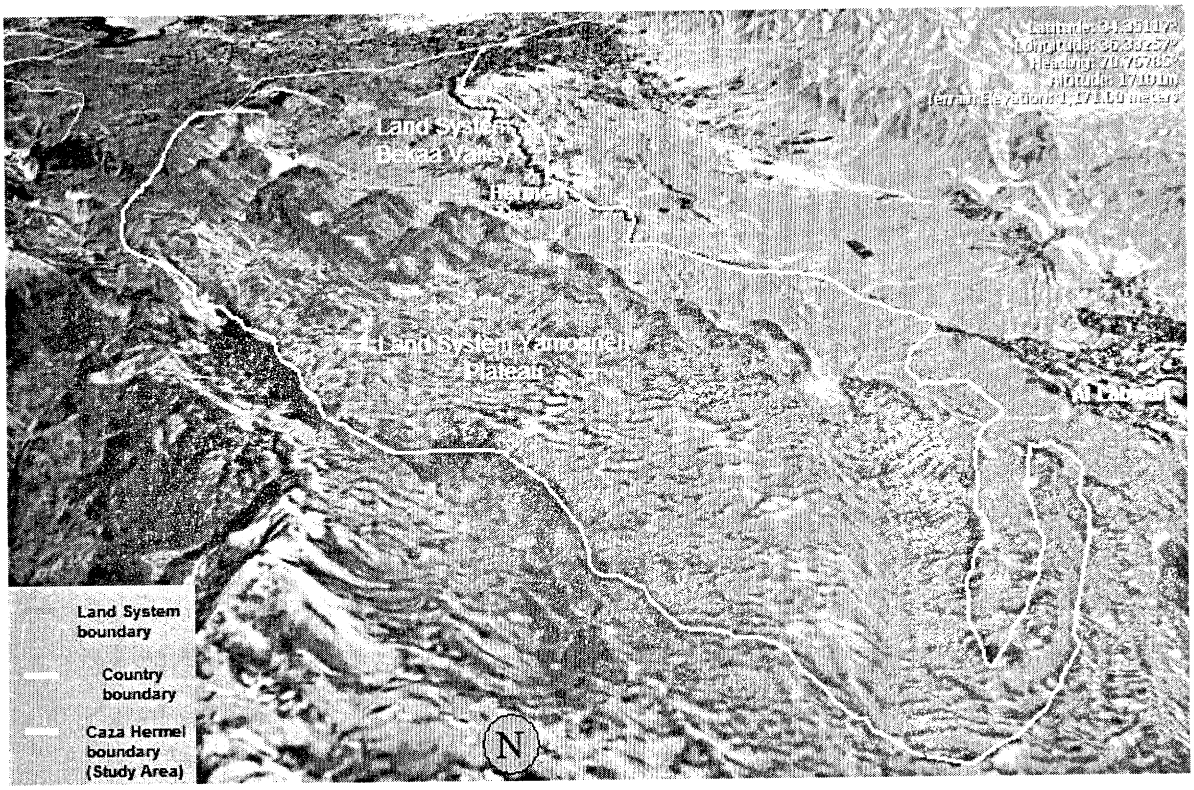


Figure 31. Land Systems boundaries identified on colour composites from satellite images in the Hermel Study Area, Lebanon (satellite image from NASA, 2004).

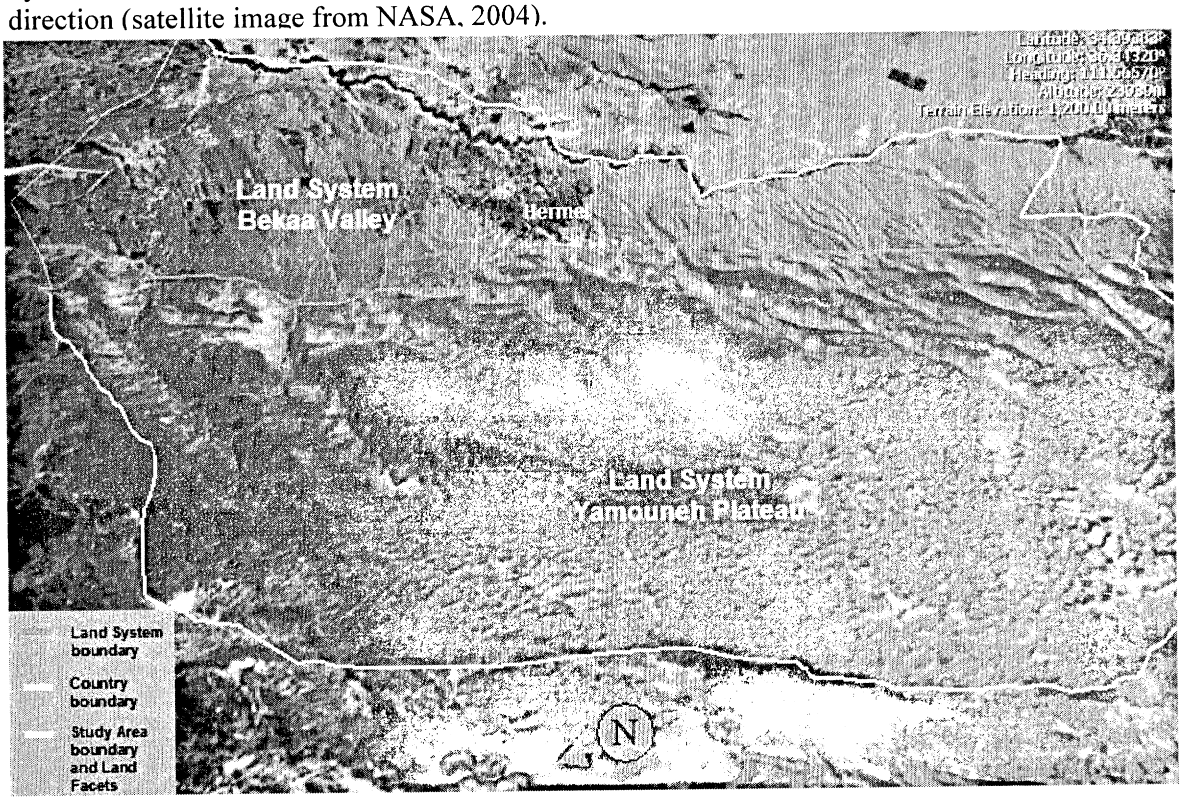


Figures 32 a and b. Oblique perspectives on 3-D landscape models of the Land Systems identified in the Hermel area from draped satellite image composites (satellite image from NASA, 2004).

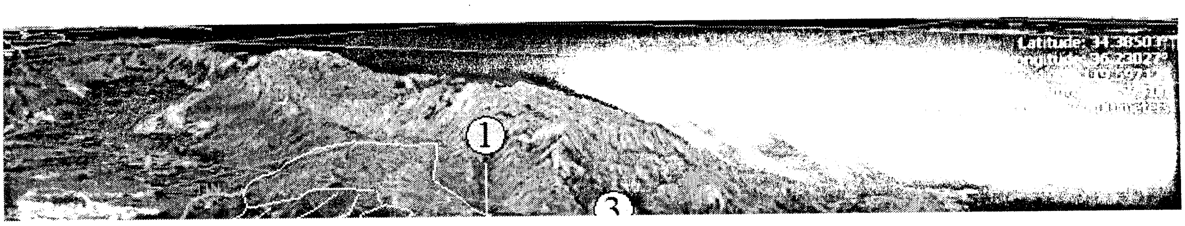




Figures 33 a and b. Oblique and orthogonal perspectives on 3-D landscape models of the Land Systems identified in the Hermel area from draped satellite image composites from a westerly direction (satellite image from NASA, 2004).



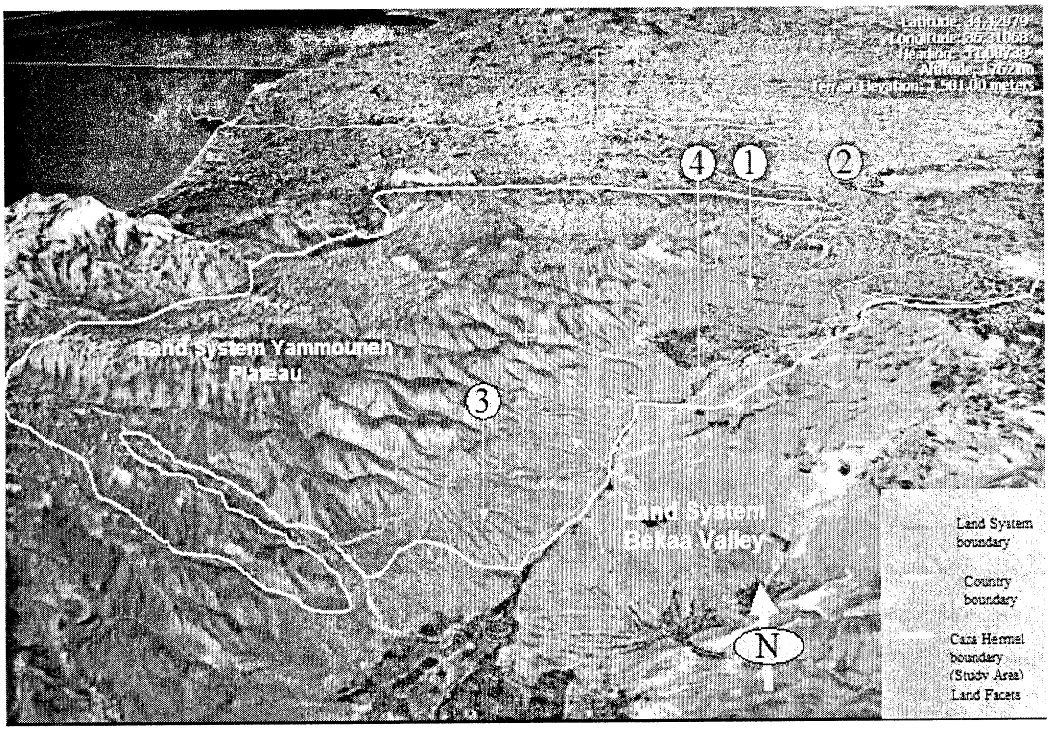
The Land Facets for the Land System "Yamouneh Plateau" are mapped out in the 3-D models shown in Figures 34a-b and characterized and described in the Table 12. The labels on the images correspond to the Land Facet identifier number in Table 12.



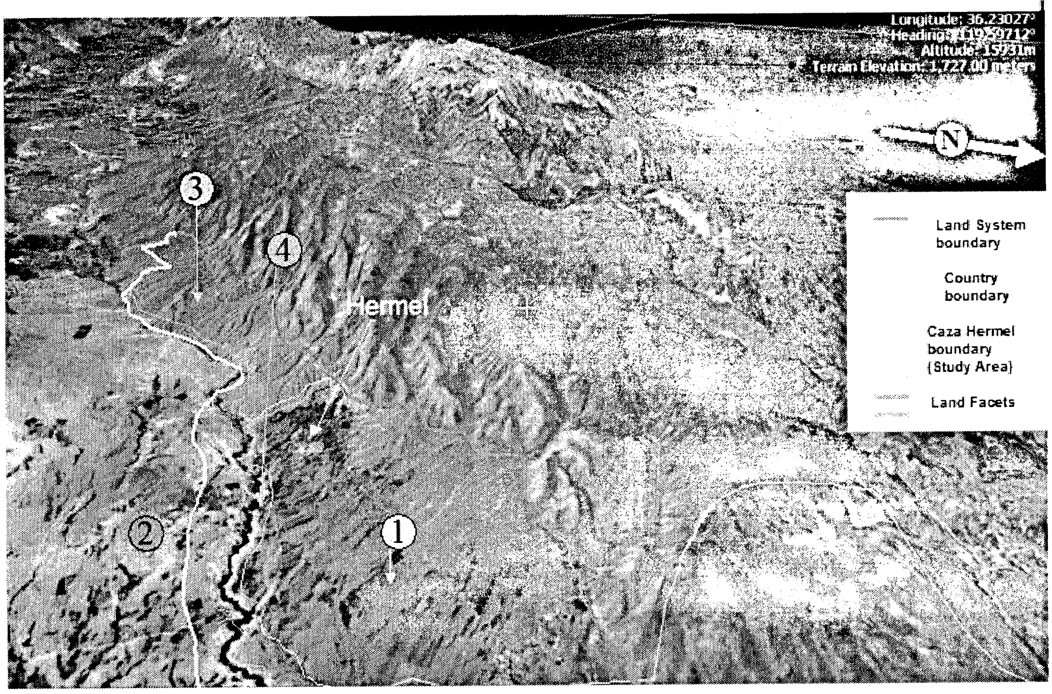
Facet ID	Land form	Rock	Soils	Land Use Type/ Land cover	Hydrology and Moisture Regime
1	Highland Plateau and narrow dissected flat upland plains of Mount Lebanon	Cretaceous and Jurassic sedimentary and carbonate rocks: greywacke, limestone, marls	Haplic Luviols, some shallow and skeletal	Cold and low sparse grasslands, sparse tree cover (<10%) or non-vegetated	Contributing site, limit of watershed, head waters of seasonal streams, low water retention capacity
2	Sloping lands of the edge of the plateau and crevices on headwaters of ephemeral streams and erosional features	Cretaceous and Jurassic sedimentary and carbonate rocks: flysch (greywacke, limestone, marls)	Associations of Lithic Leptosols, Haplic and Leptic Luvisols . Some shallow and skeletal.	Predominantly open semi-desert shrubs low grasses and some cultivated grasses	Contributing site, excessive surface drainage, and low water retention capacity. Erosional features in channels and rills.
3	Extended natural, concave drainage and sloping catchments and channels of ephemeral streams terminating in and coalescing with alluvial fans and pediments.	Carbonate rocks limestone and marls from Cretaceous and Jurassic, characterized by strong erosional features in channels and ephemeral streams, and connected to Miocene alluvial fans	Association of predominantly Lithic Leptosols, Haplic and Leptic Luvisols and Calcic Fluvisols in ephemeral stream channels and streambeds. Shallow soils highly eroded by water	Semi-desert sparse shrubs and a very low and sparse tree cover (<10%) brush and shrubs mixed with scattered natural grasses.	Intermediate site, receiving considerable runoff contributions from plateau and upland plains into hillside slopes, veneered with ephemeral stream features of steep, seasonally draining streambeds, arroyos and gullies dissecting areas with considerable laminar surface runoff
4	Convex, inter-drainage lobatted slopes and hills defining long inter-stream lands with north-eastern orientation and aspect, connecting to gentle extended slopes of alluvial fans and pediments, with clastic and alluvial deposits strongly dissected by seasonal streambeds	Cretaceous and Jurassic carbonated rocks Quaternary alluvium and sediments overlain and mixed with clastic materials, siltstones, limestones and marls.	Association of predominantly Lithic Leptosols, Haplic and Leptic Luvisols and Calcic Fluvisols in banks of ephemeral streambeds. Some shallow and skeletal soils with varying degrees of erosion.	Predominantly grasslands mixed with cropland and open shrubland of dry hills	Convex sites mainly contributing drainage to neighbouring ephemeral streambeds through seasonal runoff and forming erosional features. Extensive presence of rills of various sizes and gullies. Low water holding capacity.

Table 12. Land Facets of the Land System “Yamouneh Plateau” and their biophysical attributes and characteristics.

Similarly, the Land Facets for the Land System "Bekaa Valley" are mapped out in the 3-D models shown in Figures 35a-b and characterized and described in the Table 13. The labels in the images correspond to the Land Facet identifier number in Table 13.



Figures 35 a-b. The Land Facets of Land System "Bekaa Valley", Hermel, Lebanon (satellite image from NASA, 2004).



Facet ID	Land form	Rock	Soils	Land Use Type/ Land cover	Hydrology and Moisture Regime
1	Extended, smooth, convex and sloppy (8-30%) alluvial fans and undulating (5-8%) alluvial areas	Cretaceous sedimentary rocks and Quaternary alluvial depositions in fans and flatlands, including siltstones, muds, sandstones and carbonate clastic rocks	Association of Haplic Luvisols, Leptic Luvisols and Calcic Fluvisols. Soils of medium depth to shallow.	Croplands interspersed with semi-desert open shrubs and sparse tree cover (<10%)	Intermediate site, receiving considerable runoff and sediment contributions from plateau and upland plains through streambeds and elongated catchments of ephemeral streams. In turn, sloping alluvial fans contribute runoff and sediments to alluvial plains
2	Flatlands of undulating (5-8%) and gentle (<5%) slopes. Typical alluvial plains	Tertiary sedimentary rocks including carbonated siltstones, muds and Quaternary Alluvium	Association of Haplic Luvisols, Leptic Luvisols and Calcic Fluvisols. Medium to deep soils	Croplands punctuating semi-desert open shrubland and grass crops with very spare tree cover (< 5%)	Receiving site of runoff, sediments and alluvium, with medium to high water retention capacity. Depositional alluvial site.
3	Extended alluvial fans and pediments, slopping (8-30%) and highly dissected by erosional features: rills and gullies.	Cretaceous carbonate rocks, limestone and marls, overlain by Miocene and Quaternary sediments and alluvial materials forming typical alluvial fans	Association of predominantly Haplic Luvisols, Leptic Luvisols and Calcic Fluvisols. Medium depth to shallow soils.	Low sparse grasslands mixed with semi-desert open shrubs and a very low and very sparse tree cover (<5%) and brush.	Intermediate site, receiving considerable runoff contributions from plateau and upland plains through hillside slopes, veneered with ephemeral stream features of steep, seasonally draining streambeds, arroyos and gullies dissecting areas with considerable laminar surface runoff
4	River channels, river beds and river banks	Cretaceous sedimentary rocks underlying Quaternary alluvium and sediments mixed with clastic fluvial materials.	Leptic Luvisols and Calcic Fluvisols in banks, channels and riverbeds. Medium depth to deep soils.	Predominantly cropland mixed with grassland and open shrubland.	Typical receiving sites. Highest moisture content of all Land System, including riparian

Table 13. Land facets of the land system “Bekaa Valley” and their characteristics.

2. Results from the use of the land degradation indicators in the assessment

The assessment was conducted by each of the Land Facets in the two Land Systems in the Hermel area. The indicators used were those selected and compiled for the framework in Table 7 of the prior chapter. As far as possible these indicators were used based solely on the data and information available from reports. There was no possible way to obtain information from direct observations in the field, or to obtain data and information from interviews with farmers or local experts. Thus, the results obtained make a number of assumptions on the data from reports and existent databases. With this in view, the results of the assessment can only be taken as preliminary at best. However, they serve as a "proof of concept" of the methodological framework here proposed.

Data and information from existent databases and reports were collated, compiled and synthesized. It was possible then to determine the approximate value or status of each of the majority of the indicators selected, and whether or not they were relevant and applicable to the Land Facet in turn. This process was tedious and lengthy without digital automation (i.e. without counting on the Indictor Decision Support System and without the Framework's "Toolbox", having to access methods and procedures manually. A further constraint was the lack of direct information from the field. The processing of indicators was made manually and in a sequence of one at a time. The DPSIR chart in Figure 10 was of great assistance to this end.

3. Results from the integration of the land degradation indicators and the use of the mapping legend

The compilation of results and integration of indicators was assisted by the use of the proposed ESCWA mapping legend. Again, this process was performed without the assistance of the Integration Decision Support Tool. Therefore it was very involved and time-consuming. Eventually, it was possible to obtain a coded legend for each of the Land Facets within the two Land Systems assessed for the three types of degradation, physical, chemical and biological, identify the processes responsible and their intensity and extent. The results of this manual integration are tabulated and provided in Tables 14 and 15 for the Land Systems "Yamouneh Plateau" and "Bekaa Valley" respectively.

4. Results from the attribution of causality (driving forces and pressures) to the current states of land degradation in each Land Facet in the studied area

In the processing of indicators, data and background information from existent documents and databases and consequent integration, made it possible to be able to identify the most likely causes, in terms of driving forces and pressures, of the current states of land degradation per each Land Facet. The driving forces and pressures identified in the area were tabulated and coded so as to be able to incorporate them in the symbology (sort of mathematical equation) of the coded legend, according to the proposed legend design. The synthesis of data and information existent in reports and databases, aided by intuitive expert judgment of the evaluator, allowed for the identification of driving forces and pressures at work in each of the Land Facets of the two Land Systems comprising the Hermel studied area. The results of such synthesis of causal chains are compiled in Tables 16 and 17.

Facet ID	Land form	Rock	Soils	Land Use Type/ Land cover	Status of Land Degradation (According to proposed DPSIR legend)
1	Highland Plateau and narrow dissected flat upland plains of Mount Lebanon	Cretaceous and Jurassic sedimentary and carbonate rocks: greywacke, limestone, marls	Haplic Luviols, some shallow and skeletal	Cold and low sparse grasslands, sparse tree cover (<10%) or non-vegetated	**[P(5se; 5ser; 3co; 3cr) + B(5lc; 5om; 4bio) + C(4f; 2tx)]**
2	Sloping lands of the edge of the plateau and crevices on headwaters of ephemeral streams and erosional features	Cretaceous and Jurassic sedimentary and carbonate rocks: flysch (greywacke, limestone, marls)	Associations of Lithic Leptosols, Haplic and Leptic Luvisols, shallow to medium depth soils	Predominantly open semi-desert shrubs low grasses and some cultivated grasses	**[P(5se; 5seg; 5ser; 3cr) + B(5lc; 5om; 4bio) + C(4f;)]**
3	Extended natural, concave drainage and sloping catchments and channels of ephemeral streams terminating in and coalescing with alluvial fans and pediments.	Carbonate rocks limestone and marls from Cretaceous and Jurassic, characterized by strong erosional features in channels and ephemeral streams and connected to Miocene alluvial fans	Association of predominantly Lithic Leptosols, Haplic and Leptic Luvisols and Calcic Fluvisols in ephemeral stream channels and streambeds. Shallow and skeletal.	Semi-desert sparse shrubs and a very low and sparse tree cover (<10%) brush and shrubs mixed with scattered natural grasses.	**[P(5se; 5seg; 5ser; 5cr) + B(5lc; 5om; 5bio) + C(5f; 2tx)]**
4	Convex, inter-drainage lobatted slopes and hills defining long inter-stream lands with north-eastern orientation and aspect, connecting to gentle extended slopes of alluvial fans and pediments, with clastic and alluvial deposits strongly dissected by seasonal streambeds	Cretaceous and Jurassic carbonated rocks Quaternary alluvium and sediments overlain and mixed with clastic materials, siltstones, limestones and marls.	Association of predominantly Lithic Leptosols, Haplic and Leptic Luvisols and Calcic Fluvisols in banks of ephemeral streambeds. Predominantly shallow soils	Predominantly grasslands mixed with cropland and open shrubland of dry hills	**[P(5se; 5seg; 5ser) + B(5lc; 5om; 5bio) + C(5f)]**

Table 14. Assessment of the status of land degradation in the Land System "Yamouneh Plateau", resulting from the application of the ESCWA methodological framework

Facet ID	Land form	Rock	Soils	Land Use Type/ Land cover	Status of Land Degradation (according to proposed DPSIR legend)
1	Extended, smooth, convex and sloppy (8-30%) alluvial fans and undulating (5-8%) alluvial areas	Cretaceous sedimentary rocks and Quaternary alluvial depositions in fans and flatlands, including siltstones, muds, sandstones and carbonate clastic rocks	Association of Haplic Luvisols, Leptic Luvisols and Calcic Fluvisols	Croplands interspersed with semi-desert open shrubs and sparse tree cover (<10%)	**[P(5se; 5ser; 3cr; 5sed; 4sefl) + B(5lc; 5om; 4bio) + C(4f; 2sa; 2tx)]**
2	Flatlands of undulating (5-8%) and gentle (<5%) slopes. Typical alluvial plains	Tertiary sedimentary rocks including carbonated siltstones, muds and Quaternary Alluvium	Association of Haplic Luvisols, Leptic Luvisols and Calcic Fluvisols	Croplands punctuating semi-desert open shrubland and grass crops with very spare tree cover (< 5%)	**[P(5se; 4co; 3cr; 5sed; 5sefl) + B(5lc; 5om; 4bio) + C(5f; 4sa; 3na; 3tx)]**
3	Extended alluvial fans and pediments, slopping (8-30%) and highly dissected by erosional features: rills and gullies.	Cretaceous carbonate rocks, limestone and marls, overlain by Miocene and Quaternary sediments and alluvial materials forming typical alluvial fans	Association of predominantly Haplic Luvisols, Leptic Luvisols and Calcic Fluvisols	Low sparse grasslands mixed with semi-desert open shrubs and a very low and very sparse tree cover (<5%) and brush.	**[P(5se; 5ser; 3cr; 5sed) + B(5lc; 5om; 4bio) + C(5f; 2sa; 2tx)]**
4	River channels, river beds and river banks	Cretaceous sedimentary rocks underlying Quaternary alluvium and sediments mixed with clastic fluvial materials.	Leptic Luvisols and Calcic Fluvisols in banks, channels and riverbeds.	Predominantly cropland mixed with grassland and open shrubland.	**[P(5se; 5ser; 5seg; 5sed; 5sefl) + B(5lc; 5om) + C(3f; 3sa; 4tx)]**

Table 15. Assessment of the status of land degradation in the Land System "Bekaa Valley", resulting from the application of the ESCWA methodological framework

Table 16. Driving Forces and Pressures causing land degradation in Land System "Yamouneh Plateau", Caza Hermel, Lebanon

CODE	DRIVING FORCES	CODE	PRESSURES	LAND FACETS AFFECTED
CV	Climatic Variability	1	Increased drought frequency	1, 2, 3, 4
		2	Average air temperature changes	
		3	Increased frequency of erosive rainfall events and surface runoff	1, 2, 3, 4
		4	Increased frequency of high velocity winds causing dust	
		5	Unfavourable rainfall quantity, intensity and distribution	1, 2, 3, 4
		6	Increased water losses through runoff and evapo-transpiration	3, 4
		7	Increased water demands by plants, animals and humans	
		8	Increase aridity and favourable conditions for soil compaction and hardpan formation.	1, 2, 3, 4
ND	Natural disasters	1	Volcanic eruptions and their effects on the landscape	
		2	Earth-quakes	
		3	Tornados	
		4	Dust storms and their erosive effect	
		5	Landslides	2, 3, 4
		6	Fire	
AL	Adverse Landscape conditions	1	Terrain roughness (restrictive rapid topographical changes)	2, 3, 4
		2	Slope steepness	2, 3, 4
		3	Position on slope (unfavourable)	2, 3, 4
		4	Mining, quarrying and extracting activities (e.g. clay)	
		5	Earthworks modifying the landscape unfavourably	4
		6	Weak soil structure and texture	
		7	Rockiness and stoniness (surface and sub-surface)	1, 2, 3, 4
		8	Soil depth (restrictive)	1, 2, 3, 4
		9	Depth to water table	
AP	Animal Populations	1	Pressures by High Animal and/or Livestock Densities (e.g. decreased biomass, soil compaction, etc.)	1
		2	Surpassed animal carrying capacity of grasslands/rangelands/forests.	1
		3	Poor livestock and forage (grasses) diversity	
		4	Invasion of excessive animal populations	
		5	Habitat recession and disappearance	
PP	Primary Productivity	1	Decline in Primary Production of Ecosystems	1, 2, 3, 4
		2	Increased demands of forest products	
		3	Recess of land cover area/increased exposure to erosive forces	1, 2, 3, 4
		4	Increased demands of bio-energy	1
		5	Nutrient exports ("mining")	1, 2
		6	Soil organic matter and Carbon depletion	1, 2
PS	Personal safety	1	Conflict & violence (presence & frequency)	1, 2, 3, 4
		2	Volatile political and rural policy system	1, 2, 3, 4
FI	Food insecurity	1	Crop yield decreases in past 3 or more years	
		2	Frequency of total crop failures	
		3	Low value of production/unit area	
		4	Increased in deficit of production of staple foodstuffs locally	1
		5	Low per capita calorie/protein intake	

CODE	DRIVING FORCES	CODE	PRESSURES	LAND FACETS AFFECTED
		6	% Malnourished (underweight) rural children under 5	
WI	Water insecurity	1	Change in water availability per capita	1
WI	Water insecurity	2	Increased distance to water supply & collection	
		3	Increased time spent in collecting water	
		4	Deterioration of water quality (increased turbidity and /or contamination)	3
		5	Low % of rural population with access to water	
EI	Energy insecurity	1	Affordability and accessibility to main energy source (unfavourable to biomass)	1, 2, 3, 4
		2	Changes in main energy source	2, 3, 4
		3	Main fuel sources	
LO	Loss of opportunity	1	Migration (permanent/seasonal)	
		2	Poverty gap index/income	
		3	Land tenure constraints (type, access)	
		4	Access to common cultivable land Ha/farmer	
DC	Demographic changes	1	Population growth rate (higher demands on resources)	1, 2, 3, 4
		2	Population density (high pressures on the land and resources)	1, 2, 3, 4
		3	Age/gender distribution & occupation (unfavourable to land stewardship and lack of involvement of women)	1, 2, 3, 4
		4	Aging farming population and increase in young landless people	
		5	Migration of the young and /or poor participation in rural community affairs.	
		6	Rural infant mortality rate (per 1000 live births)	
		7	Change in non-farm employment	
		8	Unemployment rate	
LI	Level of investment	1	% National budget in rural and agricultural development	1, 2, 3, 4
		2	Lack of personal investment in the land and land activities	1, 2
		3	Lack or low government investment in land programs in rural areas.	1, 2, 3
		4	Low level of Government/institutional staff involvement in agricultural research and extension	
		5	Research and investment focus on crops vs. resources	
AC	Access	1	Credit availability (lack of)	
		2	Presence/use of banking institutions (lack of)	
		3	Access to markets of input & output supplies (distance, transportation, type)	
LT	Land Tenure	1	Uncertainty of land tenure	
		2	Unregulated, unrestricted use of common lands	3, 4
LP	Land Policies	1	Tax exemptions i.e. for large-scale farms.	
		2	Land tax or incentives for certain land use types of high intensity.	
		3	Absence or non-enforced by-laws on land-use and protection	1, 2, 3, 4
MA	Macro-economic policies	1	Legislation for natural resource management (absent or non-enforced)	1, 2, 3, 4
		2	Globalisation, trade agreements and barriers unfavourable to small, self-sustaining (non-export) farmers, or limiting export/import opportunities to them.	1, 2, 3, 4
		3	Manipulated rural investment policies and exchange rates to favour exports.	
		4	Policies to reduce farm income volatility i.e. produce	

CODE	DRIVING FORCES	CODE	PRESSURES	LAND FACETS AFFECTED
		5	Price guarantees	
MI	Micro - economic policies	1	Credit schemes favouring a certain produce	
		2	Introduction of untested and unsuitable land use types	1, 2
PR	Privatisation	1	Farmer groups/associations/co-operatives (absent or weak)	
IS	Institutional support	1	Lack of knowledge of institutional support	
IS	Institutional support	2	Ignorance of regulatory frameworks	1, 2, 3, 4
		3	Cumbersome requirements of institutions & bureaucracies	
		4	Absence or weak natural resource institutions	
TR	Transport	1	Density/type of road networks (unfavourable or poor)	
		2	Availability/accessibility of public transport (lack of)	
WA	Water	1	Lack of stream/storm/runoff control structures	1, 2, 3, 4
		2	Water distribution system (adequacy or absence)	
		3	Sewage/road runoff collection & treatment (adequacy)	
SW	Solid Waste	1	Access to latrines	
HO	Housing	1	Waste disposal type, location, proximity to population (absence or adequacy)	
ED	Education/ Skills/ Knowledge	1	Low literacy rate and education	
		2	Difficult access to schools	
		3	Availability of extension services/agricultural education	
		4	Availability of environmental education (lack)	1, 2, 3, 4
CU	Culture	1	Lack of land stewardship	1, 2, 3, 4
		2	Lack of livestock management culture	1, 2, 3, 4
HE	Health	1	Lack of sexual /family planning education	
		2	Days/year unable to work on land due to illness or poor health	
		3	Indigenous technical knowledge of land management & resource extraction	

Table 17. Driving Forces and Pressures causing land degradation in Land System "Bekaa Valley", Caza Hermel, Lebanon.

CODE	DRIVING FORCES	CODE	PRESSURES	LAND FACETS AFFECTED
CV	Climatic Variability	1	Increased drought frequency	1, 2, 3, 4
		2	Average air temperature changes	
		3	Increased frequency of erosive rainfall events and surface runoff	1, 2, 3, 4
		4	Increased frequency of high velocity winds causing dust	
		5	Unfavourable rainfall quantity, intensity and distribution	1, 2, 3, 4
		6	Increased water losses through runoff and evapo-transpiration	1,2, 3
		7	Increased water demands by plants, animals and humans	
		8	Increase aridity and favourable conditions for soil compaction and hardpan formation.	1, 2, 3
ND	Natural disasters	1	Volcanic eruptions and their effects on the landscape	
		2	Earth-quakes	
		3	Tornados	

CODE	DRIVING FORCES	CODE	PRESSURES	LAND FACETS AFFECTED
		4	Dust storms and their erosive effect	
		5	Landslides	1, 2, 3
		6	Fire	
AL	Adverse Landscape conditions	1	Terrain roughness (restrictive rapid topographical changes)	1, 3
		2	Slope steepness	
		3	Position on slope (unfavourable)	
		4	Mining, quarrying and extracting activities (e.g. clay)	
		5	Earthworks modifying the landscape unfavourably	1, 3
		6	Weak soil structure and texture	
		7	Rockiness and stoniness (surface and sub-surface)	
		8	Soil depth (restrictive)	1, 3
		9	Depth to water table	
AP	Animal Populations	1	Pressures by High Animal and/or Livestock Densities (e.g. decreased biomass, soil compaction, etc.)	1, 2, 3
		2	Surpassed animal carrying capacity of grasslands/rangelands/forests.	1, 2, 3
		3	Poor livestock and forage (grasses) diversity	
		4	Invasion of excessive animal populations	
		5	Habitat recession and disappearance	
PP	Primary Productivity	1	Decline in Primary Production of Ecosystems	1, 2, 3,
		2	Increased demands of forest products	
		3	Recess of land cover area/increased exposure to erosive forces	1, 2, 3, 4
		4	Increased demands of bio-energy	
		5	Nutrient exports ("mining")	1, 2, 3
		6	Soil organic matter and Carbon depletion	1, 2, 3
PS	Personal safety	1	Conflict & violence (presence & frequency)	1, 2, 3, 4
		2	Volatile political and rural policy system	1, 2, 3, 4
FI	Food insecurity	1	Crop yield decreases in past 3 or more years	1, 2
		2	Frequency of total crop failures	1, 2
		3	Low value of production/unit area	
		4	Increased in deficit of production of staple foodstuffs locally	
		5	Low per capita calorie/protein intake	
		6	% Malnourished (underweight) rural children under 5	
WI	Water insecurity	1	Change in water availability per capita	1, 2, 3, 4
		2	Increased distance to water supply & collection	
		3	Increased time spent in collecting water	
		4	Deterioration of water quality (increased turbidity and /or contamination)	4
		5	Low % of rural population with access to water	
EI	Energy insecurity	1	Affordability and accessibility to main energy source (unfavourable to biomass)	1, 2, 3
		2	Changes in main energy source	1, 2, 3
		3	Main fuel sources	
LO	Loss of opportunity	1	Migration (permanent/seasonal)	
		2	Poverty gap index/income	
		3	Land tenure constraints (type, access)	1, 2, 3

CODE	DRIVING FORCES	CODE	PRESSURES	LAND FACETS AFFECTED
		4	Access to common cultivable land Ha/farmer	
DC	Demographic changes	1	Population growth rate (higher demands on resources)	1, 2, 3, 4
		2	Population density (high pressures on the land and resources)	1, 2, 3, 4
		3	Age/gender distribution & occupation (unfavourable to land stewardship and lack of involvement of women)	1, 2, 3, 4
		4	Aging farming population and increase in young landless people	
		5	Migration of the young and /or poor participation in rural community affairs.	
		6	Rural infant mortality rate (per 1000 live births)	
		7	Change in non-farm employment	
		8	Unemployment rate	
LI	Level of investment	1	% National budget in rural and agricultural development	1, 2, 3, 4
		2	Lack of personal investment in the land and land activities	1, 2, 3
		3	Lack or low government investment in land programs in rural areas.	1, 2, 3, 4
		4	Low level of Government/institutional staff involvement in agricultural research and extension	
		5	Research and investment focus on crops vs. resources	1, 2
AC	Access	1	Credit availability (lack of)	
		2	Presence/use of banking institutions (lack of)	
		3	Access to markets of input & output supplies (distance, transportation, type)	
LT	Land Tenure	1	Uncertainty of land tenure	
		2	Unregulated, unrestricted use of common lands	
LP	Land Policies	1	Tax exemptions i.e. for large-scale farms.	
		2	Land tax or incentives for certain land use types of high intensity.	1, 2
		3	Absence or non-enforced by-laws on land-use and protection	1, 2, 3, 4
MA	Macro-economic policies	1	Legislation for natural resource management (absent or non-enforced)	1, 2, 3, 4
		2	Globalisation, trade agreements and barriers unfavourable to small, self-sustaining (non-export) farmers, or limiting export/import opportunities to them.	1, 2, 3, 4
		3	Manipulated rural investment policies and exchange rates to favour exports.	
		4	Policies to reduce farm income volatility i.e. produce	
		5	Price guarantees	
MI	Micro - economic policies	1	Credit schemes favouring a certain produce	
		2	Introduction of untested and unsuitable land use types	1, 2
PR	Privatisation	1	Farmer groups/associations/co-operatives (absent or weak)	
IS	Institutional support	1	Lack of knowledge of institutional support	
IS	Institutional support	2	Ignorance of regulatory frameworks	1, 2, 3, 4
		3	Cumbersome requirements of institutions & bureaucracies	
		4	Absence or weak natural resource institutions	
TR	Transport	1	Density/type of road networks (unfavourable or poor)	
		2	Availability/accessibility of public transport (lack of)	
WA	Water	1	Lack of stream/storm/runoff control structures	1, 2, 3, 4

CODE	DRIVING FORCES	CODE	PRESSURES	LAND FACETS AFFECTED
		2	Water distribution system (adequacy or absence)	
		3	Sewage/road runoff collection & treatment (adequacy)	
SW	Solid Waste	1	Access to latrines	
HO	Housing	1	Waste disposal type, location, proximity to population (absence or adequacy)	2, 4
ED	Education/ Skills/ Knowledge	1	Low literacy rate and education	
		2	Difficult access to schools	
		3	Availability of extension services/agricultural education	
		4	Availability of environmental education (lack)	1, 2, 3, 4
CU	Culture	1	Lack of land stewardship	1, 2, 3, 4
		2	Lack of livestock management culture	
HE	Health	1	Lack of sexual /family planning education	
		2	Days/year unable to work on land due to illness or poor health	
		3	Indigenous technical knowledge of land management & resource extraction	

5. *Results from the integration of causality (driving forces and pressures) to the current states of land degradation according to the mapping legend*

The results of identifying driving forces and pressures in each Land Facet assessed, allowed for the complete coding of the legend in each Land Facet according to the proposed legend-coding scheme. In this way it was possible to prepare a map that reflected a coded legend with codes for each of the following information:

- Kind of land degradation (physical, chemical and biological) taking place.
- Type of process at work (within each of the kinds above)
- Intensity of the degradation process causing the state of degradation.
- Spatial extent of the process at work and of the state caused
- Driving forces and pressures likely causing such processes and states

The final coded legends for each of the Land Facets and Land Systems assessed in the Hermel case study are shown in Tables 18 and 19.

6. *Mapping results from land degradation assessment according to the DPSIR approach in the Hermel study area.*

The results of the assessment, after their coding and tabulation could then be amenable to be assigned to a land unit's map as attributes of the mapped units (Land Facets) for representation of the spatial variability of the assessment. The process then becomes a simple attribute assignment to a polygon representing the mapped land unit. The map of the Hermel study area is shown in Figure 36 and the same map with land degradation attributes as labels is shown in Figure 37.

Table 18. Coded legend describing the type, process, intensity, extent and causes (driving forces and pressures) of land degradation in each Land Facet of the Land System Yammouneh Plateau", Hermel, Lebanon.

Land Facet	Status of Land Degradation (DPSIR legend) in Land System "Yammouneh Plateau"
1	$\left[P\left(\frac{5se}{100};\frac{5ser}{50};\frac{3co}{80};\frac{3cr}{80}\right)+B\left(\frac{5lc}{100};\frac{5om}{100};\frac{4bio}{100}\right)+C\left(\frac{4f}{100};\frac{2tx}{20}\right)\right]^{\frac{CV_{1,3,5,8};AL_{7,8};AP_{1,2}}{PS_{1,2};DC_{1,2};LP_{3};MA_{1,2}}}_{\frac{EI_{1,3};WA_{1};PP_{3,5,6};WI_{1}}{IS_{2};CU_{1,2}}}$
2	$\left[P\left(\frac{5se}{100};\frac{5seg}{80};\frac{5ser}{80};\frac{3cr}{50}\right)+B\left(\frac{5lc}{100};\frac{5om}{100};\frac{4bio}{100}\right)+C\left(\frac{4f}{100}\right)\right]^{\frac{CV_{1,3,5,8};ND_{2};AL_{1,2,3,7,8};PP_{1,3,5,6}}{PS_{1,2};EI_{1,2};DC_{1,2,3};LI_{1,2,3}}}_{\frac{LP_{3};MA_{1,2};MI_{2};IS_{2};WA_{1};ED_{4}}{ED_{4};CU_{1,2}}}$
3	$\left[P\left(\frac{5se}{100};\frac{5seg}{100};\frac{5ser}{100};\frac{3cr}{80}\right)+B\left(\frac{5lc}{100};\frac{5om}{100};\frac{4bio}{100}\right)+C\left(\frac{4f}{100};\frac{2tx}{100}\right)\right]^{\frac{CV_{1,3,5,6,8};ND_{3};AL_{1,2,3,7,8}}{DC_{1,2,3};PP_{1,3};PS_{1,2};EI_{1,2};LI_{1,3}}}_{\frac{LT_{2};LP_{3};MA_{1,2};IS_{3};WA_{1}}{ED_{4};CU_{1,2}}}$
4	$\left[P\left(\frac{5se}{100};\frac{5seg}{100};\frac{5ser}{100}\right)+B\left(\frac{5lc}{100};\frac{5om}{100};\frac{4bio}{100}\right)+C\left(\frac{5f}{100}\right)\right]^{\frac{CV_{1,3,5,6,8};ND_{4};AL_{2,3,7,8}}{DC_{1,2,3};PS_{1,2};PP_{1,3};EI_{1,2}}}_{\frac{LI_{1};LT_{2};LP_{3};MA_{1,2}}{IS_{2};WA_{1};ED_{4};CU_{1,2}}}$

Table 19. Coded legend describing the type, process, intensity, extent and causes (driving forces and pressures) of land degradation in each Land Facet of the Land System "Bekaa Valley", Hermel, Lebanon.

Land Facet	Status of Land Degradation (DPSIR legend) in Land System "Bekaa Valley"
1	$\left[P\left(\frac{5se}{100};\frac{5ser}{100};\frac{3cr}{80};\frac{5sed}{100};\frac{5sefl}{100}\right)+B\left(\frac{5lc}{100};\frac{5om}{100};\frac{4bio}{100}\right)+C\left(\frac{4f}{100};\frac{2sa}{20}\frac{2tx}{20}\right)\right]^{\frac{CV_{1,3,5,6,8};ND_5;AL_{1,5,8};}{DC_{1,2,3};PS_{1,2};AP_{1,2};PP_{1,3,5,6}}}_{\frac{FI_{1,2};WI_1;EI_{1,2};LO_3;LI_{1,2,3,5}}{LP_{2,3};MA_{1,2};MI_2;IS_2;WA_1;ED_4;CU_1}}$
2	$\left[P\left(\frac{5se}{100};\frac{4co}{80};\frac{3cr}{80};\frac{5sed}{100};\frac{5sefl}{100}\right)+B\left(\frac{5lc}{100};\frac{5om}{100};\frac{4bio}{100}\right)+C\left(\frac{5f}{100};\frac{4sa}{30};\frac{3na}{20};\frac{3tx}{20}\right)\right]^{\frac{CV_{1,3,5,6,8};ND_5;DC_{1,2,3};AP_{1,2}}{PS_{1,2};PP_{1,3,5,6};FI_{1,2};WI_1;EI_{1,2}}}_{\frac{LO_3;LI_{1,2,3,5};LP_{2,3};MA_{1,2};MI_2}{IS_2;WA_1;HO_1;ED_4;CU_1}}$
3	$\left[P\left(\frac{5se}{100};\frac{5ser}{100};\frac{3cr}{80};\frac{5sed}{100}\right)+B\left(\frac{5lc}{100};\frac{5om}{100};\frac{4bio}{100}\right)+C\left(\frac{5f}{100};\frac{2sa}{30};\frac{3na}{20};\frac{2tx}{20}\right)\right]^{\frac{CV_{1,3,5,6,8};ND_5;AL_{1,5,8};DC_{1,2,3}}{PS_{1,2};AP_{1,2};PP_{1,3,5,6};WI_1;EI_{1,2}}}_{\frac{LO_3;LI_{1,2,3};LP_3;MA_{1,2}}{IS_2;WA_1;ED_4;CU_1}}$
4	$\left[P\left(\frac{5se}{100};\frac{5ser}{100};\frac{5seg}{100};\frac{5sed}{100};\frac{5sefl}{100}\right)+B\left(\frac{5lc}{100};\frac{5om}{100}\right)+C\left(\frac{3f}{100};\frac{3sa}{30};\frac{4tx}{30}\right)\right]^{\frac{CV_{1,3,5};DC_{1,2,3};PS_{1,2}}{PP_3;WI_{1,4};LI_{1,3};LP_3}}_{\frac{MA_{1,2};IS_2;WA_1}{HO_1;ED_4;CU_1}}$

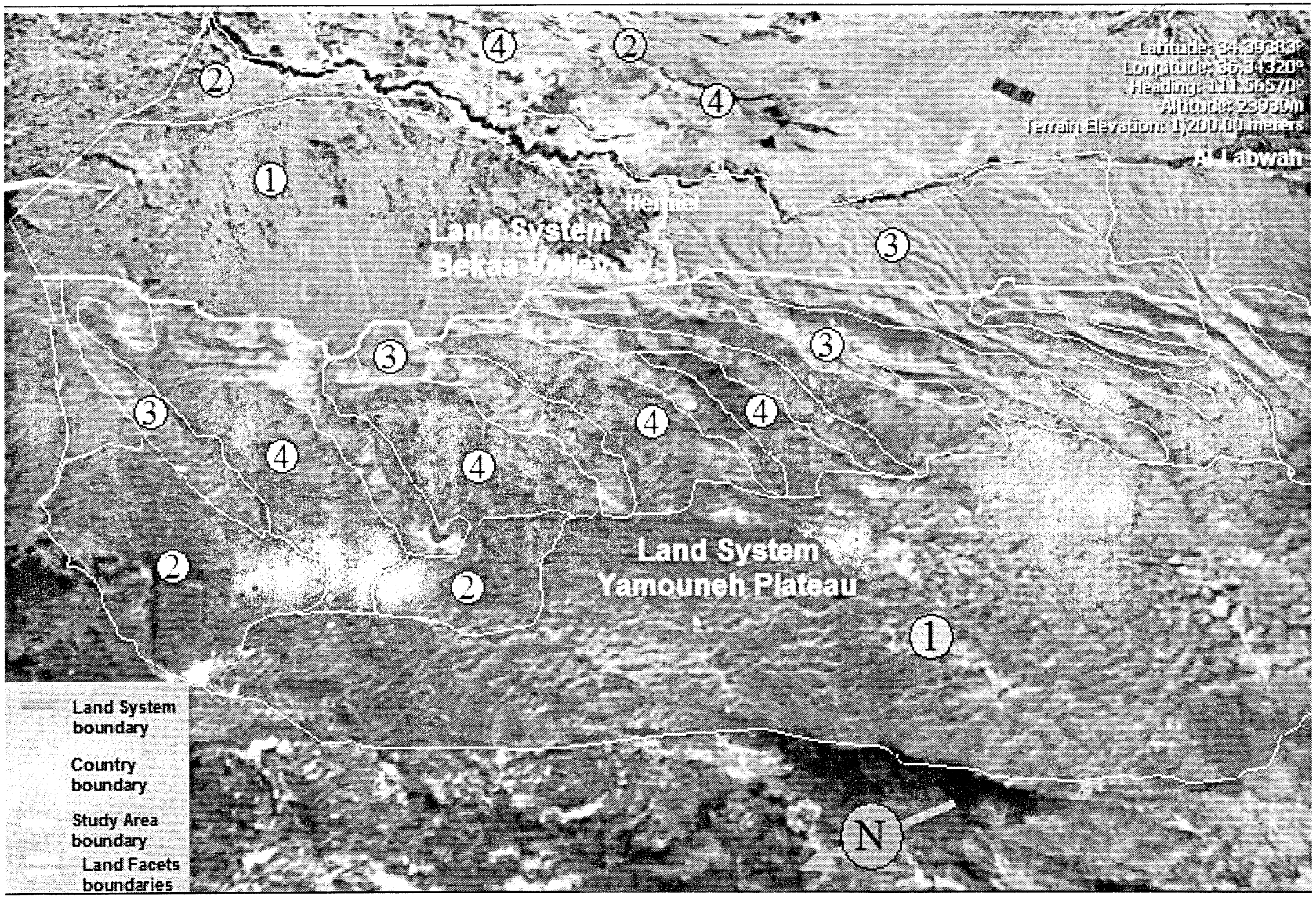


Figure 36. Land Facets map of the Hermel study area in North Central Lebanon (satellite image from NASA, 2004).

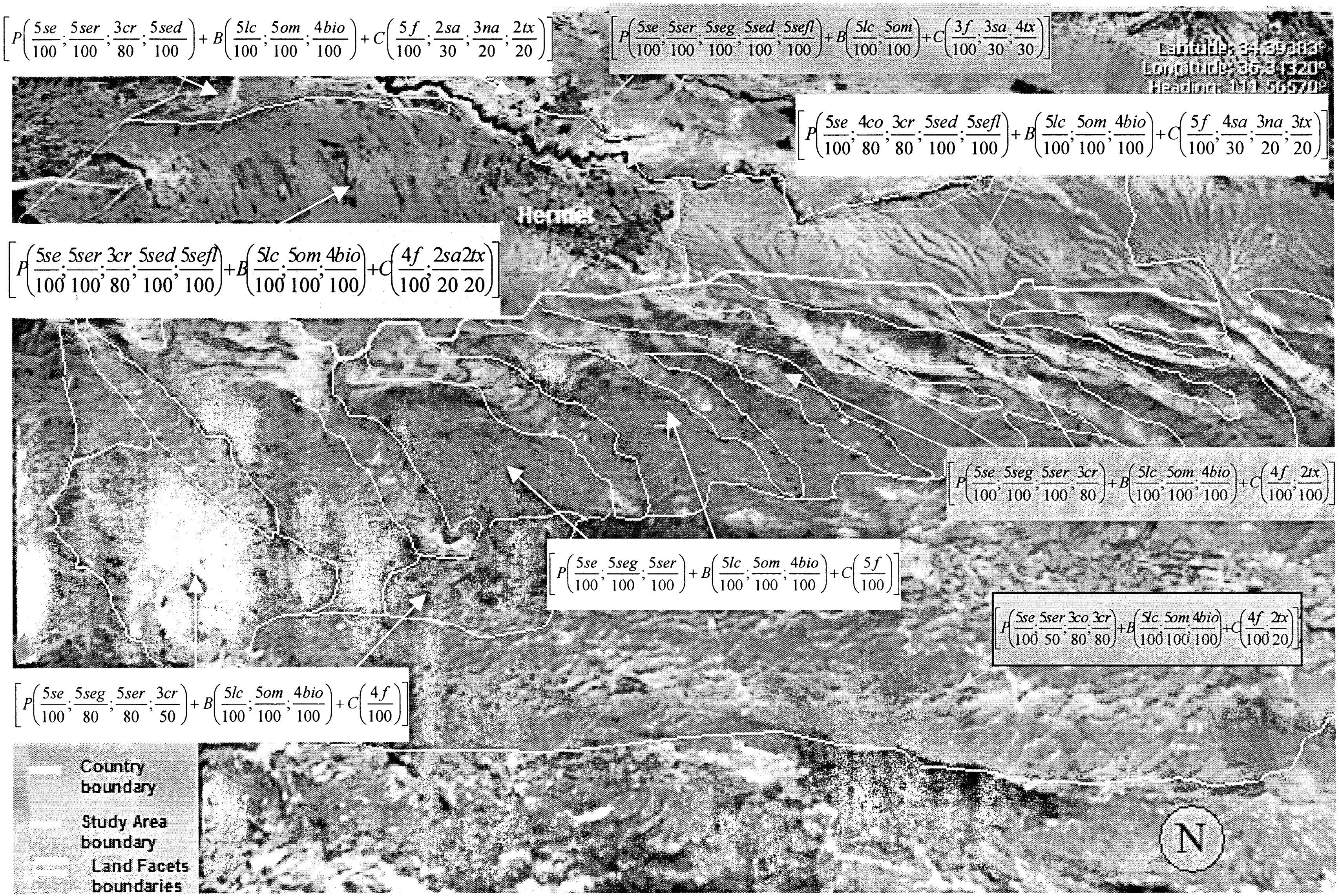


Figure 37. Land Degradation map of the Hermel study area in North Central Lebanon, according to the DPSIR legend (satellite image from NASA, 2004).

7. *Establishing Networks of Causal Chains for land degradation in the Hermel study area*

The data collected from reviewed reports, databases and maps were compiled and organised into categories of driving forces, pressures, states, impacts and responses for each of the capitals: natural (biophysical), social, human, financial/institutional and infrastructural. With this organizing principle, it was possible to map out a preliminary network of causal chains for driving forces, the pressures caused and the resulting states of degradation under the DPSIR approach. The networks for natural, social and economic and financial driving forces are shown in Figures 38, 39and 40, respectively, to illustrate the kinds of results that can be obtained. Figure 41 contains the connections between states and the expected impacts of degradation on people's livelihoods.

D. DISCUSSION OF RESULTS

The land in the Caza Hermel area in Lebanon is intensely to severely degraded and its spatial extent indicates that most of the area comprehended in this administrative unit is affected by intense and severe states of land degradation of all kinds: physical, chemical and biological. The dominant type of land degradation in both, spatial extent and intensity is physical and among this, soil erosion by water is identified as the most pervasive agent of land degradation, followed by biological (organic matter loss and loss of land cover and soil biodiversity) and chemical degradation caused by loss of soil fertility through nutrient "mining", soil salinity and other element imbalances, (i.e. soil pollutants). Biological and chemical degradation are also important in both, intensity and extent of the degradation processes. Soil salinity is a very localized chemical degradation process, associated with irrigation and cropping, therefore occurring mainly in the flatlands of the valley.

It was possible to identify driving forces and pressures in the area through the researched documents and databases. The methodological framework proposed here enabled this process greatly, but required a substantial amount of work and familiarization with the socio-political and economic problems of the area. Data processing for this aspect of the methodological framework is not easy due to the complexity of the linkages, which requires the acquisition of an in-depth knowledge of the area. It is not difficult to ascertain that amongst the main driving forces and pressures exerted are the many years of war and its devastating effect on the fabric of society and particularly on the ability to implement appropriate land stewardship. This is a fundamental factor. Land care and environmental protection are not a priority for farmers and land users in the studied area, against the background of the need for survival and the satisfaction of the most fundamental human needs. Many social and economic factors stemming from or directly linked to conflict are also parallel effects of war and civil strife.

1. *Types, extent and severity of land degradation and its causes in Hermel, Lebanon*

Recorded and reported field observations and measurements at specific sampling sites, together with observations reported while studying the test area allowed for an assessment of the state of land degradation in the two Land Systems studied. The evaluation of the state of land degradation, in terms its type, extent and severity was made in each land facet. The land use types present in the study area include rangeland and cropland, each exerting different pressures on the land, combining with and being modified by the position of the assessed area on the landscape. Severe and very severe land degradation is generalized across the Land Systems in the Hermel area, particularly in the rangelands. More acute physical land degradation caused by the

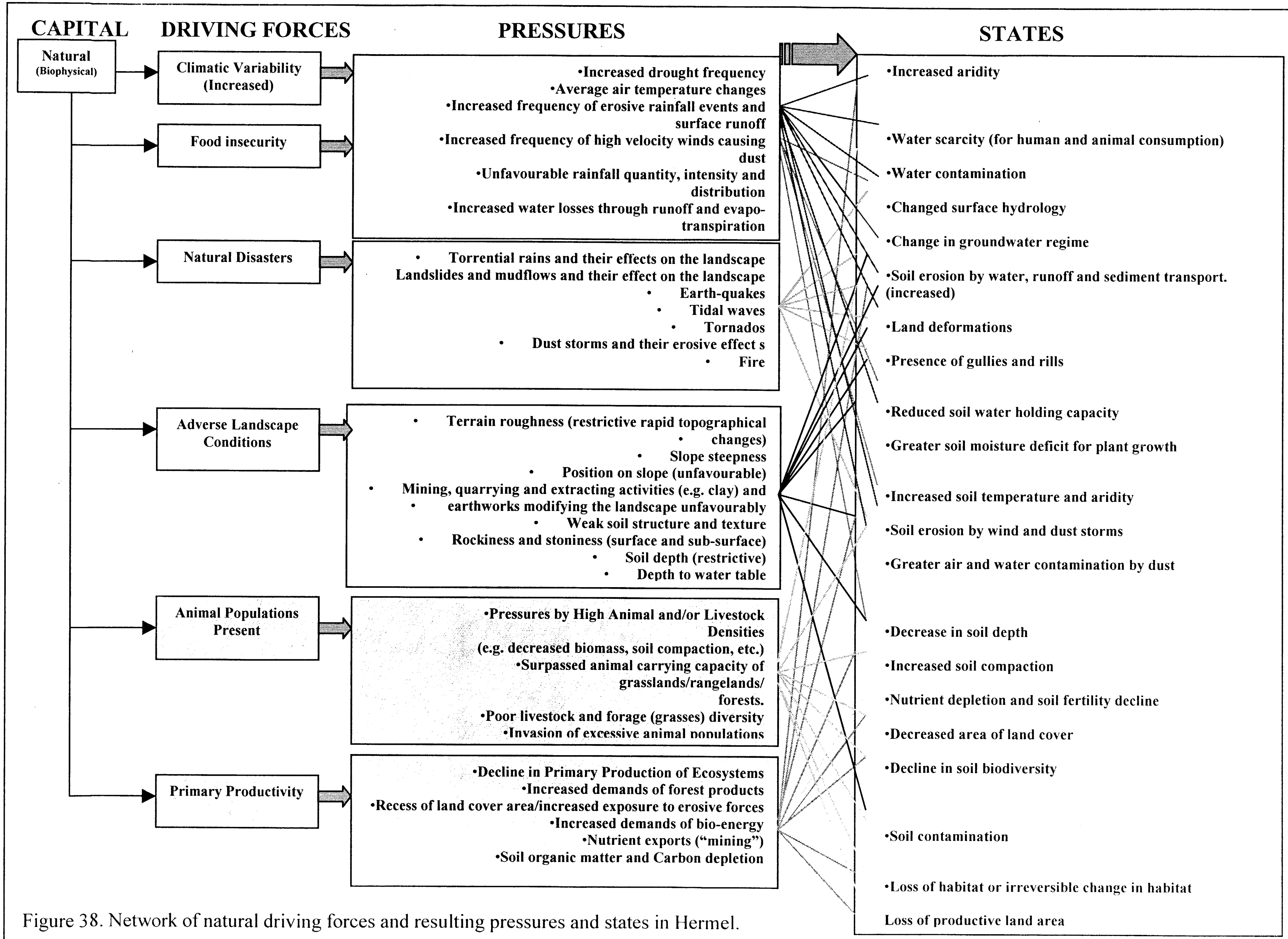
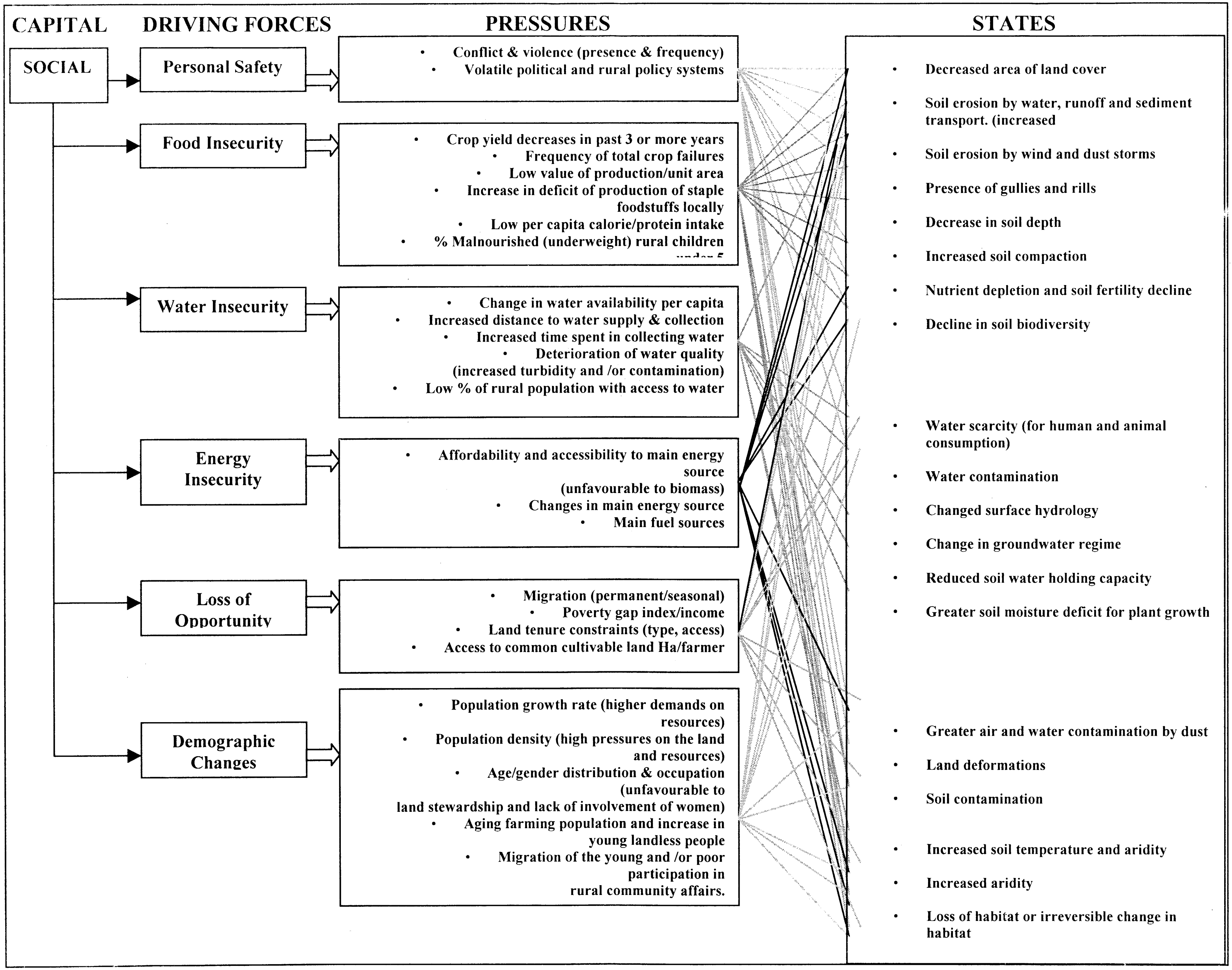


Figure 38. Network of natural driving forces and resulting pressures and states in Hermel.


CAPITAL
DRIVING FORCES
PRESSURES
STATES
SOCIAL
Personal Safety
Food Insecurity
Water Insecurity
Energy Insecurity
Loss of Opportunity
Demographic Changes
• Conflict & violence (presence & frequency)
• Volatile political and rural policy systems
• Crop yield decreases in past 3 or more years
• Frequency of total crop failures
• Low value of production/unit area
• Increase in deficit of production of staple foodstuffs locally
• Low per capita calorie/protein intake
• % Malnourished (underweight) rural children
• Change in water availability per capita
• Increased distance to water supply & collection
• Increased time spent in collecting water
• Deterioration of water quality (increased turbidity and /or contamination)
• Low % of rural population with access to water
• Affordability and accessibility to main energy source (unfavourable to biomass)
• Changes in main energy source
• Main fuel sources
• Migration (permanent/seasonal)
• Poverty gap index/income
• Land tenure constraints (type, access)
• Access to common cultivable land Ha/farmer
• Population growth rate (higher demands on resources)
• Population density (high pressures on the land and resources)
• Age/gender distribution & occupation (unfavourable to land stewardship and lack of involvement of women)
• Aging farming population and increase in young landless people
• Migration of the young and /or poor participation in rural community affairs.
• Decreased area of land cover
• Soil erosion by water, runoff and sediment transport. (increased
• Soil erosion by wind and dust storms
• Presence of gullies and rills
• Decrease in soil depth
• Increased soil compaction
• Nutrient depletion and soil fertility decline
• Decline in soil biodiversity
• Water scarcity (for human and animal consumption)
• Water contamination
• Changed surface hydrology
• Change in groundwater regime
• Reduced soil water holding capacity
• Greater soil moisture deficit for plant growth
• Greater air and water contamination by dust
• Land deformations
• Soil contamination
• Increased soil temperature and aridity
• Increased aridity
• Loss of habitat or irreversible change in habitat

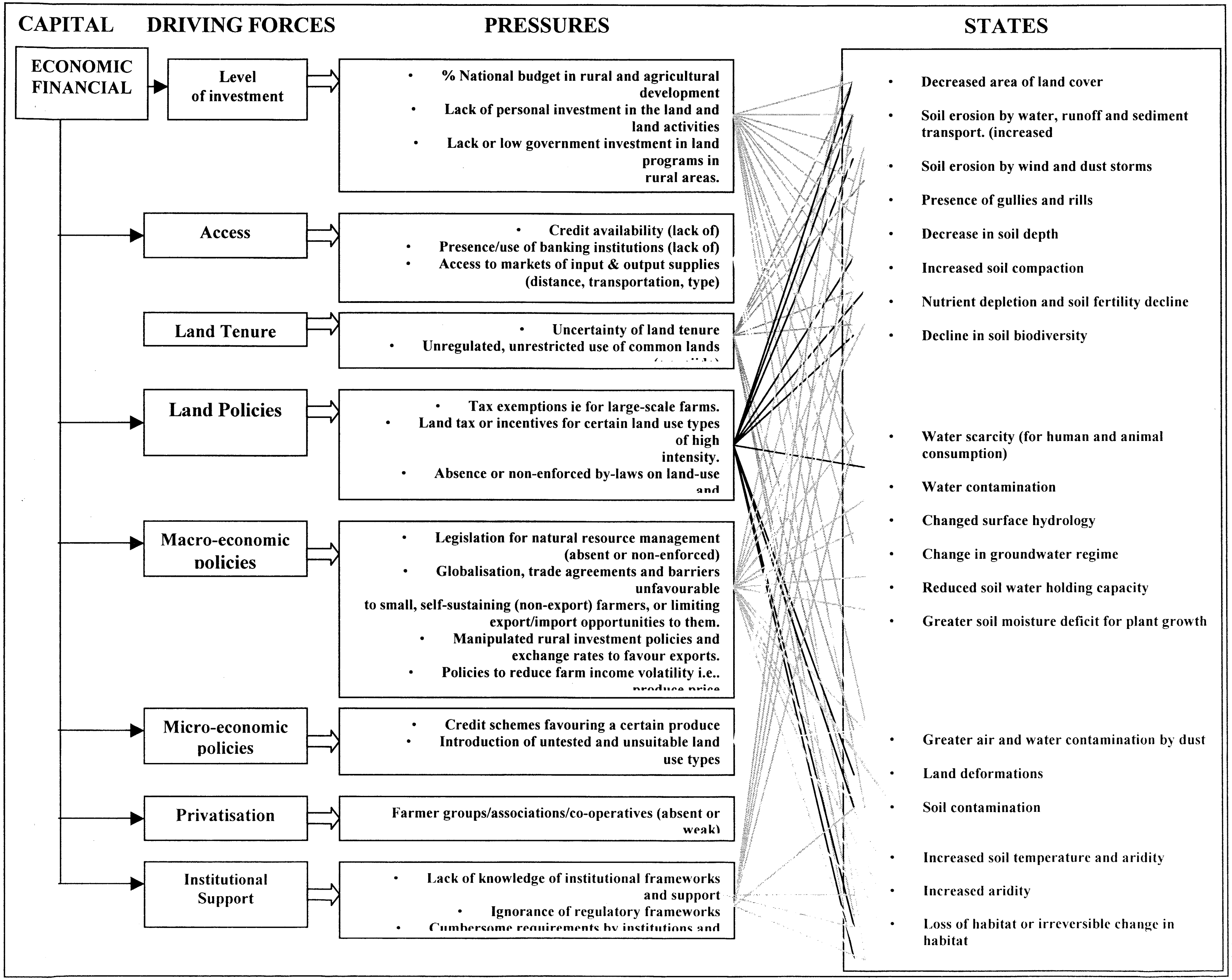


Figure 40. Networks of economic driving forces, pressures and states in Hermel, Lebanon

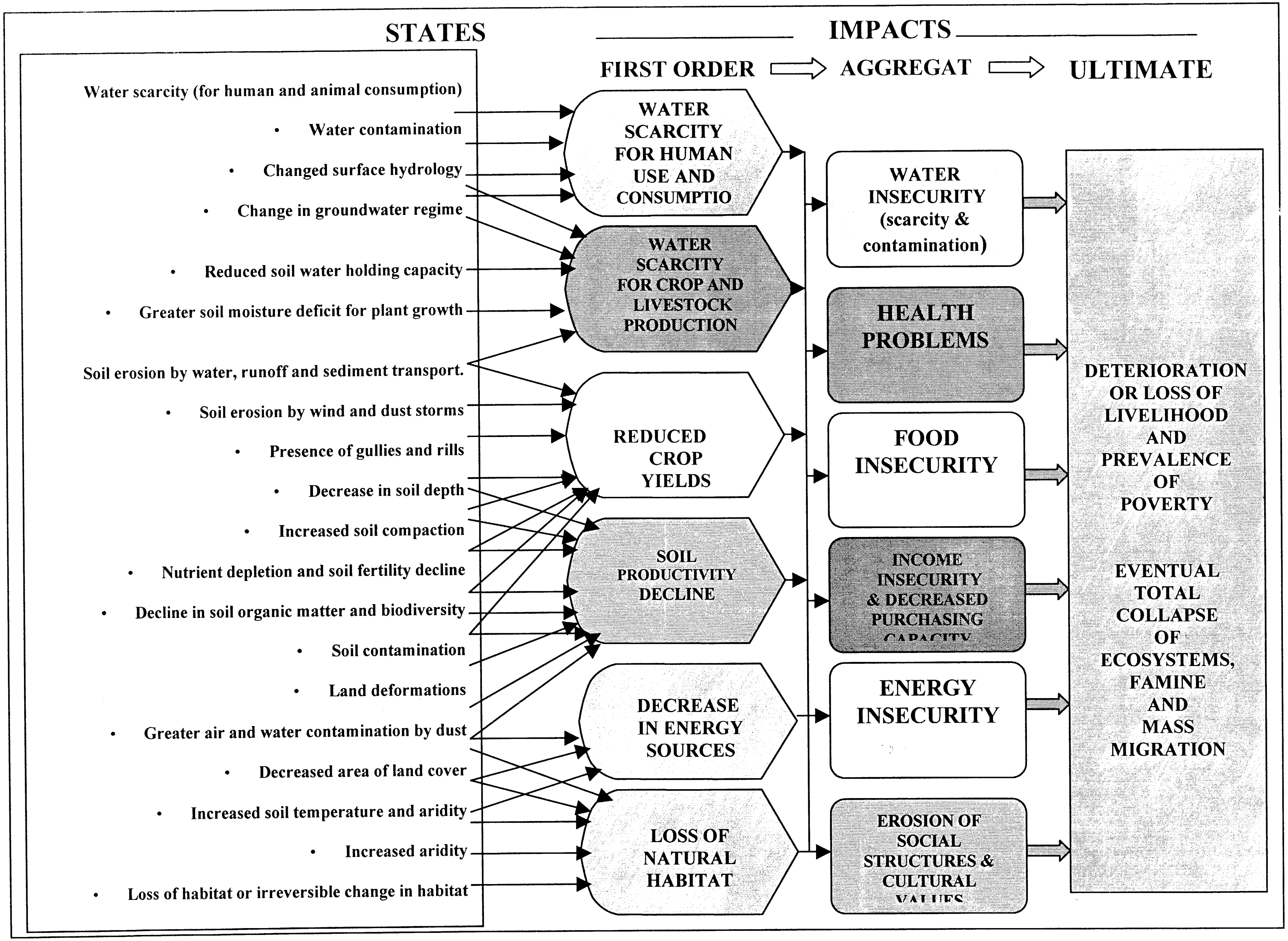


Figure 41. State and impacts of land degradation in Hermel.

processes of soil erosion by water and wind is observed in rangelands, as evidenced by the presence of marked and well developed rills and gullies of considerable size.

As far as land degradation being part of a larger conundrum of environmental problems, the main issues contributing to the problems of environmental protection in Lebanon are related to the unclear definitions of roles of partners in environmental protection, a lack of coordination of goals with the private sector and problems with enforcement. The roles of the various ministries and government institutions involved in environmental protection are not clearly defined, resulting in overlapping areas of responsibility, inefficiency and in some cases conflict.

VI. METHODOLOGICAL FRAMEWORK REQUIREMENTS

A. Requirements for Applying the Proposed Methods

The three main controlling factors that determine data needs and the adequacy of data for the methods to be used in an assessment are:

i. The degree of detail and the accuracy with which the type of land degradation process is to be identified and its intensity and extent quantified and predicted.
ii. The scale at which such identification and quantification is required
iii. The detail and grain with which the identification and quantification need to be reported.

The ideal situation would be to measure, count, quantify, etc. the whole range of data sets to operate all the modules in the framework described. However, in many situations not all the modules may be required, hence, it is more pertinent to judge the adequacy of a method in terms of its required minimum dataset.

1. Minimum data sets

For the methods used in these exercises it was found that the minimum data set consists of the following:

- **Land Degradation Indicators**: these set is essential to the assessment. The identification of the relevant degradation indicators to a given area is key to the success of the assessment. The minimum indicator dataset required is dictated by the kind of natural capital and the particular manifestations of the social, financial and physical capitals in the area of concern. The decision support systems proposed as part of the framework become very relevant in supporting the selection of indicators.
- **Maps**: Topographic contour map as a base map, soils map (any level of generalization but preferably at the level of soil series and associations), geologic map and land cover/vegetation/land use map.
- **Images:** remotely sensed imagery (satellite and/or air-photographs) are very desirable but not essential at the scale of a farmer's plot. However, they become essential at scales pertinent to the local, district, regional or national levels of assessment.
- **Data and information:** Demographic and census data, recent agricultural, forestry, livestock and land-use statistics, economic activity statistics and institutional frameworks operating in the area. Information about policies concerning agricultural, livestock and forestry programs and policies concerning the use and conservation of land resources, including industrial and urban.
- **Field data (if possible but necessary at the local level):** These data are to be gathered directly from farmers, herders, foresters and land users in the area through structured close and open-ended questionnaires and field data forms. The former is to gather data on all indicators concerning the human interventions and the circumstances around land-use type and intensity and the behaviour of the land, including land productivity. The latter concerns the measuring of all biophysical indicators to help establish the state land degradation, type, intensity and extent.

The data contained in the minimum dataset are standard and are generally available in many parts of the world. Therefore, it can be concluded that the methodological framework is adequate to perform assessments and that it would be possible to conduct them from an average situation of data availability in many parts of the world. The methodological framework would produce better assessment results as more specific datasets for more sophisticated tools become available (e.g. model parameters in nutrient dynamic simulation, etc.). Thus, the method is not demanding on data and flexible enough to accommodate to situations where only the minimum dataset is available, to situations where data for highly sophisticated modeling and analytical tools may be present.

2. *Hardware and software*

In terms of the hardware and software required to apply the methodological framework the following are essential:

- Computer (desktop or notebook) with standard or average capabilities, except in storage and speed of processing, for which upper-end data processing and storage space capabilities are required.
- Printed materials (questionnaires and field forms), pencils and markers.

In terms of the software requirements for the application of the procedures in the methodological framework, the following are desirable and become essential, depending, again, on the grain and detail desired in the results, the scale and the nature of the physical, chemical and biological processes in operation in the area and the indicators to be estimated or measured. The software components are:

- Geographical Information Systems (GIS) software
- Remote Sensing image processing (RS) software
- Simulation and Process Modelling software
- Standard data processing programs (e.g. spreadsheets, databases, graphics and text processor).

Of the above, only the latter are essential. GIS, RS and modelling software have now become standard tools in many agencies. Lower-end to medium software capabilities should suffice. GIS, RS and modelling are highly desirable and become essential depending on the scale. Both GIS and particularly RS are fundamental in up-scaling and downscaling estimates and site observations of indicators, therefore, they should be part of the "toolbox" of the framework.

The methods used in the case study reported here were not demanding in terms of hardware and software capabilities for their application in conducting land degradation assessments at the scale of a medium to small watershed or village to farm level only when the minimum datasets are available and when medium to coarse grain in detail and quantification are required.

3. *Technical Knowledge of Personnel*

Concerning the technical knowledge of personnel conducting the assessment the methodological framework used could be very demanding in terms of the knowledge and experience of the assessor. The complexity of integrating social, economic and demographic data and policy information to biophysical data in terms of causal chains of driving forces to pressures causing states of degradation represents the greatest challenge. It was judged that the minimum knowledge and experience required were those of an able and resourceful professional (minimum BSc. or B.A.), provided clear guidance will be available in the form of a technical manual. The most demanding challenges, methodologically speaking, in terms of knowledge and experience are the following:

i. The selection of an adequate set of indicators relevant to the area of the assessment, form the very large list of indicators available, and their relevant threshold values to the area being assessed.
ii. The integration of the social, economic and demographic data to the biophysical data and their organization in terms of capitals within the DPSIR approach, their driving forces and the pressures derived from them that lead to the states of degradation. In other words, being able to map out the networks of causal chains operating in the area of the assessment from the seemingly vast array of multifarious data gathered from interviews, field forms and printed reports and statistics, and the results from modelling and estimation.
iii. The required subjective judgement to determine the values of intensity and extent of the various types of degradation processes operating in the area of the assessment, as per the proposed legend. In other words, the translation of the data in the field forms into a legend code for the degradation map.

The latter, has still an element of subjectivity, which is inescapable when only the minimum datasets are available, and when computerized modelling tools and the data to feed them are not available. Further development and testing of the methodological framework are required, in order to be able to derive a step-by-step manual, which could lower the requirements of knowledge and experience of technical personnel performing the assessment.

VII. CONCLUSIONS AND POLICY RECOMMENDATIONS

i. CONCLUSIONS ABOUT THE TYPES, EXTENT AND SEVERITY OF LAND DEGRADATION IN HERMEL, LEBANON

The land in the Caza Hermel area in Lebanon is intensely to severely degraded and its spatial extent indicates that most of the area comprehended in this administrative unit is affected by intense and severe states of land degradation of physical, chemical and biological kinds. Severe and very severe land degradation is generalized across the Land Systems in the Hermel study area, particularly in the rangelands and croplands. The most acute physical land degradation is caused by sheet, rill and gully soil erosion by water, with the latter causing strong land deformations. Thus, the dominant type of land degradation in both, spatial extent and intensity is physical soil erosion by water. This is identified as the most pervasive agent of land degradation, followed by biological (organic matter loss and loss of land cover and soil biodiversity) and chemical degradation caused by loss of soil fertility through nutrient "mining", soil salinity and other element imbalances, (i.e. soil pollutants). Soil salinity is a very localized chemical degradation process, associated with irrigated cropping, therefore occurring mainly in the flatlands of the valley and areas suitable for irrigation.

ii. CONCLUSIONS ABOUT THE CAUSES OF LAND DEGRADATION IN HERMEL, LEBANON

It was possible to identify driving forces and pressures in the area through the researched documents and databases. The methodological framework proposed here enabled this process greatly, but required a substantial amount of work and familiarization with the socio-political and economic problems of the area. Data processing for this aspect of the methodological framework is not easy due to the complexity of the linkages, which requires the acquisition of an in-depth knowledge of the area. It is not difficult to ascertain that amongst the main driving forces and pressures exerted on the land are the many years of war and its devastating effect on the fabric of society and particularly on the ability to implement appropriate land stewardship. This is a fundamental factor. Land care and environmental protection are not a priority for farmers and land users in the studied area, particularly when placed against the background of the need for survival and the satisfaction of the most fundamental human needs, including personal safety. Many social and economic factors stemming from or directly linked to conflict are also parallel effects of war and civil strife.

Legislation tends to be reactive and only enacted out of necessity and there is a lack of coordination between public and the private sectors. Environmental enforcement remains a major weakness of the environmental control system and explains land degradation. The causes are identified as a lack of clarity and internal inconsistencies in legal and regulatory texts, and from institutional weaknesses, special interests, and political interference that stand in the way of effective enforcement. The civil war is one of the major contributing factors to Lebanon's foes, since it stretched from 1975 to 1991. It left Lebanon in economic crisis, making environmental protection a lesser priority to other most immediate needs. Human displacement during the war and in the years following has distorted the population pyramid in many regions (UNDP reports that during the war half a million people were displaced and about 900 000 left the country). The resulting problems of land abandonment, an aging population with few young labourers in many regions has led to land degradation and resource deterioration.

C. CONCLUSIONS ABOUT THE PROPOSED METHODOLOGICAL FRAMEWORK

Many methods and approaches for land degradation assessment have emerged over the years. All methods exhibit a strong biophysical bias and, for the most, ignore the causes (driving forces and pressures) and impacts of land degradation on people's livelihoods. Therefore they do not provide a path or direct link to remedial actions, nor to policy formulation.

The methodological framework proposed here attempts to bring social and economic factors into an assessment framework that integrates them with the biophysical and semi-quantitative variables. A parametric semi-quantitative approach to the assessment, as exercised in this case study, allows flexibility and balance between the biophysical quantitative estimation and modelling of processes, on the one hand, and the intuitive judgment, knowledge and perception of human interactions and social and cultural values, on the other.

The DPSIR paradigm aids in the conceptualisation of the complex myriad of interrelationships of issues relating to land degradation. It provides a sound organisational framework for the indicators, particularly for the selection process, and for eventual analysis.

The framework is not simple, but neither are the problems of land degradation, particularly when they are seen through the optic of their causes and their impacts, in order to enable the formulation of policy and remedial action. Yet, the framework is complete, fully comprehensive and above all flexible. It can be adapted to a wide range of circumstances of data, technical knowledge, technology, scale and competencies in personnel. From that stand point its usefulness can be increased as its development and implementation takes incremental steps and refinement. Many tasks, particularly those of development of the automated decision support systems for the completion of the 12 core sets of tasks suggested in the framework, demand immediate attention, with the possibility of great rewards in terms of progress in completing and testing the methodology part of the proposed framework.

D. STRATEGIES FOR PROMOTING POLICIES TO COMBAT DESERTIFICATION

A complex mix of processes brings about land degradation and desertification involving interactions between political, social, economic and/or natural factors usually at multiple scales. The outcomes of these processes are highly varied and specific to each location. Therefore, it is useless to apply general prescriptions to remedy complex and unique problems.

It is also insufficient to develop and implement technical solutions to problems of resource use and management. It is equally important to address the root causes of land degradation in order to secure positive returns on investment in abatement, remediation or rehabilitation projects and programmes.

Promoting economic investment in desertification monitoring, prevention and remedial efforts is essential to combat the problem. The control of desertification requires not only a better understanding of the processes and socio-economic relations generating it at all levels, but also requires that those with economic and political power locally, nationally and internationally understand the benefits of addressing desertification.

Promoting investment in drylands is difficult as they typically have a low economic return per unit area making restoration seem a risky investment. Most national governments have not been convinced to make the capital investments needed to control desertification, as other needs are perceived to be immediate and have a greater guarantee of return on investment in a shorter time frame. In addition, the cost of restoring degraded land increases with the severity of degradation. Estimates range from $5 (USD) per hectare for slightly degraded to $1000 or more for severely degraded land (LADA, 2002), implying that the areas most in need of attention and investment generally don't receive it because of the prohibitive costs involved and the uncertainty of benefits and returns.

There may be advantages found in the convergence of disciplines that deal with global environmental issues in the sense that solutions that simultaneously improve the situation of many environmental problems will receive more attention and funding. The economic linkages between dryland degradation, carbon sequestration and climate change are important synergies to be exploited as most efforts to restore dryland productivity simultaneously sequester carbon, thus possibly creating economic incentive to restore degraded lands.

Some research has suggested that the most important policy actions are those that create incentives for private investment in land. Factors promoting investment include strong, supportive local institutions, well-specified property rights, easy access to product and credit markets and undistorted pricing of products. The largest driving precondition for land investment is the security of land tenure. These land rights must include not only the rights of use but also the right to transfer. Insecurity in land tenure causes distortion in investment incentives and as a barrier to credit availability, as lenders would assume part of the risk of land loss.

E. POLICIES NEEDED TO COMBAT LAND DEGRADATION IN THE STUDY AREA OF HERMEL, LEBANON

The reconstruction efforts following the long period of war have left Lebanon with little resources for direct investment in environmental protection. The economic benefits of combating land degradation and the synergies with other long-term goals need to be better linked and exploited.

Any policy written is only as effective as its implementation allows. For policies that address land degradation as a whole or any of the driving forces identified to be effective, appropriate institutional capacities and coordination are required for monitoring, planning and implementation. Coordination and cooperation is required within and between government Ministries and agencies and other interest groups in order to avoid overlapping research and to promote the sharing of data and the efficient use of resources and standardized methods and procedures. Standardized policies, strategies and programmes are needed also specifically for land use, integrated ecosystem and resource management plans and sustainable agriculture and rural development plans.

Local involvement is essential in local development strategies for combating land degradation. Governments should be encouraged to decentralize policy formulation and decision-making, streamlining the bureaucratic evolution of trade, price, credit, and social and economic policies. Whenever possible, multiple stakeholders, from all sectors and institutions concerned, should be included in the decision-making and priority setting processes, particularly concerning actions to prevent and arrest land degradation.

Community participation is essential to the success of most efforts to abate land degradation processes. The effects of land degradation will be obvious to those living in effected areas, but he driving forces and pressures may not be as clearly identifiable. Therefore the raising of awareness at the local level of the causes and impacts of degradation and the possible alternatives to break the land degrading processes is crucial to involve the public. Public awareness of the dimensions of the problem and its connections to poverty and livelihood deterioration should be promoted through policies geared towards environmental education. The resources and means to address the problems and implement change by rural communities is fundamental in effecting any change.

Land tenure and use are two of the main issues that need to be addressed, specifically the costs associated with registration and transactions, inheritance laws and resulting land fragmentation, the lack of stewardship of common lands, and the need for better land use planning and implementation of plans should be considered priority issues to address land degradation.

The high incidence of poverty and income disparity between and within regions needs to be addressed, particularly the rural communities dependent on weak agricultural productivity. Support for rural land users is needed to enable them to compete with foreign competition nationally and in the global market, through the allocation of more resources and the initiation of innovative solutions.

Agricultural development is essential to maintain a reasonable level of self-sufficiency in food provision and provide employment for the inevitably increasing population. In coming years intensification of farming practices and resource use will be necessary, including increased cropping frequencies and improvement of marginal lands, while still maintaining the sustainability of agriculture and improving land and water use. Agricultural research that explore these issues and identify technological alternatives and methods to improve farming system efficiency are required.

In addition, social equity needs promotion particularly considering small farms and marginal lands. These goals require appropriate agricultural and economic policies that improve credit schemes, marketing of agricultural products and some degree of agrarian reform in institutions as well as an improvement of the provision of services and infrastructure in these regions.

The region suffers from scarce water resources with growing demands due to population growth, urban expansion and industrialization. These are growing pressures on land resources. The situation of limited water supply is worsened by inefficient use and unregulated groundwater withdrawals. Future generations will likely pay much higher costs per unit of domestic water, as reliance on non-conventional and typically expensive sources of water (desalination, wastewater reuse) will inevitably increase. Policies to address these issues adequately for multiple stakeholders and ahead of their becoming crisis, are required

Issues in need of prompt attention are the imbalance between the growing water demand and sustainable supply available, the limited ability to control over-extraction of groundwater from private wells, the inefficient irrigation practices, and the low or lacking water tariffs in all sectors that tend to lead to inappropriate and inefficient water use.

F. RECOMMENDED FOLLOW UP ACTIONS

The usefulness of the proposed methodological framework and that of the assessment results it generates can only be increased if further development and implementation of the framework takes incremental steps towards its refinement. Many tasks, particularly those of development of the automated decision support systems for the completion of the 12 core sets of tasks suggested in the framework, demand immediate attention. Actions to further develop the decision support systems and to standardize databases on indicators, methods, procedures and tools, as well as using a commonly agreed mapping legend will facilitate communication and regional and national policy formulation and cooperation. These actions have the possibility of great rewards in terms of progress in completing and testing the proposed framework and therefore producing a standardized methodology and assessment results for the entire region. The ability to compare assessment results and communicate and share datasets, indicators, models and tools between the ESCWA countries is not only desirable but essential in the improvement of assessments to guide effective policy formulation and remedial actions.

Further testing of the methodological framework in other areas in the ESCWA region over a gradient of dryness, desertification conditions, pressures on land resources and scales would make the methodology more robust and reliable. Particularly, testing sites that require the application of remote sensing, GIS, and computer simulation models and their combination with demographic and socio-economic data to find causality.

The process of integration between indicators of drivers and pressures to those of states of degradation require further testing so as to ensure that the process of identifying the networks of causal chains can be streamlined and soon can become automated. In this respect Bayesian Networks offer a promising body of theory and practical tools to those ends. However, these developments should be encouraged and supported in collaboration and with the participation of agencies, staff and scientists of the country members.

Communication and synergistic coordination of actions with those of other projects with similar mandates, for example the LADA of FAO/UNEP (GEF) project may result in economies of effort and efficient resource use. Communications between state members and their active participation in direct methodology testing and further development should be encourage and even facilitated through the implementation of regional training workshops and direct participation in testing case studies.

The economic costs of land degradation and its full implications should be address in every assessment. To this end, the economic module of the framework requires further development and testing, particularly through case studies either in the region or in very similar conditions in other regions. In this actions, partnerships with national agencies and research institutions and universities should be encouraged.

Finally, common repository databases on land resources in all their characteristics and indicators, and those of demographic and socio-economic and cultural data for the region should exist and be shared by all member states. Likewise for knowledge bases (e.g. indicators, etc.), models, computer tools, assessment protocols, mapping legends.

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APPENDIX A

Preliminary Indicator List Suggested in FAO Consultation Report (Snelband Bot, 2002).

KEY:
BP = biophysical
SE = socio-economical
I = Institutional
P = Political

Note: Scale-specific indicators only village/watershed and plot/farming system level shown here.

BIOPHYSICAL Indicators at village/watershed level	**Description**	**BP SE I P**	**DPSIR**
Bio-physical indicators			
% of irrigated area	Erosion/Land cover	BP	DP
Main fuel source	Erosion/Land cover	BPSE	P
Production of charcoal	Erosion/Land cover	BPSE	P
Most important construction material	Erosion/Land cover	BPSE	P
Seasonal water fluctuation in rivers	Erosion	BP	S
Flooding and meandering of rivers and streams	Erosion	BP	S
Bad smell of water: surface and groundwater	Erosion	BP	S
Fragile sites (ponds, creeks, wetlands)	Land cover /Erosion	BP	S
Area affected by salinization/waterlogging	Soil/Erosion	BP	S
Ground water salinization	Soil/Erosion	BP	S
Water table depth	Erosion	BP	S
Occurrence of whirlwinds	Erosion	BP	S
Occurrence of dust storms	Erosion	BP	S
Water shortage	Erosion	BP	S
Water quality/turbidity/ algal blooms	Erosion	BP	**SI**
Coverage of fertile soil by shifting sands	Soil/Erosion	BP	**SI**
Drying of wells and water sources	Erosion	BP	I
Change of permanent waters into seasonal	Erosion	BP	I
Dying trees at river banks	Erosion	BP	I
High salt content of surface water	Soil/Erosion	BP	I
Amount of sedimentation behind dams	*Erosion*	*BP*	*I*
Incidence of gullying	*Erosion*	*BP*	*I*
Adoption of soil conservation technologies	Erosion	BP	R
Protected areas	Land cover	BP	R
Number of waterharvesting structures	Erosion	BP	R
Amount of water stored in check dams	Erosion	BP	R
Reclamation of wastelands	Land cover	BP	R
Extension of depth of boreholes	Erosion	BPSE	R
Use of watershed management practices - **Revegetation/Afforestation**	*Erosion*	*BP*	*R*
Fuel efficient technologies	Erosion/Land cover	BPSE	R

BIOPHYSICAL **Indicators at farming system level**	**Description**	**BP SEIP**	**DPSIR** *
Bio-physical indicators			
Position on the slope	Land form	BP	***D***
Steepness	Land form	BP	D
Main fuel source	Erosion/Land cover	BPSE	D
Attitude towards and use of chemical fertilizers	Soil	BP	DR
Construction material (Thatched houses/wood)	Erosion/Land cover	BPSE	**DP**
Burning of crop residues	Erosion	BP	**P**
Use of by-products	Soil	BP	**P**
Use of manure, compost, litter and/or termitaria	Soil	BP	*P*R
Farming intensity - *ratio of cultivated land and fallow land*[1] - *ratio of monoculture without fallowing to land in crop rotation (F) (d, r) (*) (BP/SE)* - *length of fallow periods*[2] - *existence of intensive tillage*	Erosion	BP	*P*R
Grazing intensity - *number of livestock per hectare on grazing areas (G, N)*[3] *(d, r)* - *area covered by pasture/grazing animals (V, F) (d, r)*	Erosion	BP	*P*R
Animal mortality	Erosion	BP	S
Rooting depth	Erosion	BP	S
Crusting and slaking properties	Soil/Erosion	BP	S
Soil compaction	Soil/Erosion	BP	S
Exposure of sub-soil	Soil/Erosion	BP	S
Cropping pattern/Cover crops/ Crop rotation	Soil/Erosion	BP	SR
Protection of soil through landscape feature (use of terracing)	*Erosion/Land form*	*BP*	*SR*
Shift towards monocropping, mainly grains	Erosion	BP	I
Substitution of cattle/camel by small ruminants	Erosion	BP	I
Shift from 2-oxen ploughs to one-ox plough[4]	Erosion	BP	I
Yield and change in productivity	Soil	BP	I
Indicator plants	Soil	BP	I
Availability of supplementary wild plant species	Erosion	BP	I
Replacement of woody species by thorny bushes	Erosion	BP	I
Replacement of shrubby plants and reduction of grasses (over-grazing)	*Erosion*	*BP*	*I*
Amount of silt deposited on agricultural land	*Erosion*	*BP*	*I*

[1] (Shyamsundar, 2002)

[2] (Shyamsundar, 2002)

[3] Global data available on number of cattle, sheep and goats, equines, and buffaloes and camels in the WRI, *World Resources Report 2000 – 2001*, table FG.4.

[4] As the natural resource base is degraded, the carrying capacity will be reduced resulting in a decrease of cattle/camel: small ruminants ratio. At the same time less cattle is available for agricultural activities, like ploughing and thus a shift from two-oxen ploughs to one ox ploughs will take place.

Decline in soil fertility - *change in soil phosphorous level* - *change in nitrogen fixation capacity of soil biomass* - *change in soil organic matter* - *change in soil soluble salts* - *change in soil moisture storage capacity* - *change in soil depth*	*Soil*	*BP*	*I*
Protected areas on-farm	Erosion/Land cover	BP	R
Indigenous SWC measures	Soil/Erosion	BP	R
Use of mulch	Soil/Erosion	BP	R
Adoption of soil conservation technologies	Soil/Erosion	BP	R
Area under SWC	Soil/Erosion		
Water harvesting structures on-farm	Erosion	BP	R
Farmers that grow drought resistant species/crops that require lower nutrient requirements	*Erosion/Land cover*	*BP*	*R*
Use of livestock rotation	*Erosion*	*BP*	*R*

SOCIO ECONOMIC **Indicators at village and farmer level**	**Description**	**BP SE I**
Socio-economic indicators		
Insecurity: Food insecurity		
Presence and frequency of conflict and violence	*Conflict*	SE
Hours of available rural water supply	*Water depletion*	SE
Female headed households (*proxy*)	*Income/ Consumption*	SE
*Changing ratio of staple (subsistence) vs. cash (marketed) crops produced by women and by men	*Agricultural yields/food*	SE
*Change in quantity of household consumption derived from forest and fisheries products[5]	*Agricultural yields/food*	SE
*Increased amount of time spent to obtain water	*Water depletion*	SE
*Increased distance walked to by household members to collect water[6]	*Water depletion*	SE
Amount of meat available in market	*Malnutrition*	SE
Number of months facing hunger	*Malnutrition*	SE
Abandonment of (farm) land	*Drought or conflict*	SE
Number of households rendered homeless due to conflict	*Conflict*	SE
Change in diversity of diet (meat, legumes, eggs, fish, etc.)/ frequency of meat, poultry or fish consumption	*Malnutrition*	SE
Concern about livelihood of children[7]	*Malnutrition*	SE
Lack of opportunity		
Ease of access to land registries and titling services for women and men	*Land tenure*	SE
Ease of access to land and resources for women and men	*Land tenure*	SE

[5] This indicator emphasizes how poor people rely on natural resources during "lean" times. Natural resources are often used as a form of insurance to help poor people cope with food insecurity (Shyamsundar, 2002, p. 14 and 16). Definition used by Shyamsundar (2002, p. 26) is change in "quantity of key minor forest and aquatic produce consumed per season".

[6] Definition used by Shyamsundar (2002, p. 26) is "Distance walked by each household member to collect water per day X no. of household members X no. of days per year".

[7] Available at a national-level in the Demographic and Health Surveys by the World Bank and Macro International for some countries (see www.worldbank.org/poverty/health/data/index.htm.). Description of infant mortality in Section 2.7 of World Development Indicators, 2001, p. 69. Global-level infant mortality data available by country (World Bank, *World Development Report 2000/2001*, p. 286).

Type of land tenure	*Land tenure*	SE
High percentage of land to high income group	*Distribution of wealth*	SE
Off-farm employment for women and men	*Employment*	SE
Presence and frequency of conflict and violence over land use or natural resources	*Conflict*	SE
Quantity of annual income derived from farm (cultivation, livestock) and non-farm activities	*Employment*	SE
Availability of credit schemes	*Assets*	SE/I
Male and female access to cash and credit	*Assets*	SE/I
Number of cattle[8]	*Assets*	SE
Amount of grain stocks[9]	*Assets*	SE
Rural households with adequate water for livestock[10]	*Assets*	SE
Availability of financial services/infrastructure	*Assets*	SE/I
Presence of banking institutions	*Assets*	SE/I
Distance to nearest banking center	*Assets*	SE
Distance to nearest market	*Assets*	SE
Transport problems due to bad roads	*Assets*	SE
Price of transport	*Assets*	SE
*Land ownership[11]	*Assets*	SE/I
*Rural land/labor ratio	*Employment*	SE
*Farmers without access to cultivable land	*Marginal land*	SE
*Farmers cultivating on steep slopes or river deltas	*Marginal land*	SE
*Amount of time spent by household member to collect fuelwood and water[12]	*Marginal land*	SE
*Distance walked by household member to collect fuelwood and water[13]	*Marginal land*	SE
*Increase in cultivation on open-access areas[14]	*Marginal land*	SE
*Decline in percentage of annual household income derived from non-marketed ("wild") goods collected at local commons[15]	*Land tenure*	SE
*Decline in quantity of annual household consumption that is derived from the common land[16]	*Land tenure*	SE
*Decline in the existence of sustainable Common Pool Resource (CPR) management institutions[17]	*Land tenure*	SE
*Security of land tenure for women and men	*Land tenure*	SE/I
*Clarity of land ownership/property rights for women and men	*Land tenure*	SE/I

[8] Used as primary source of wealth and savings among most nomadic and pastoral communities (Henninger and Hammond, 2002, p. 20).

[9] Often an important source of savings/insurance in rural households.

[10] Good indicator of the ability of the poor to maintain non-land income generating assets (Shyamsundar, 2002, p. 16).

[11] Since land ownership is often required for access to credit, this indicator may be used as a proxy for access to credit.

[12] This indicator is important for understanding land degradation's impact on women and children. Definition used by Shyamsundar (2002, p. 26) is "Total time spent by each household member to collect water and fuel per day X no. of household members X no. of days per year".

[13] This indicator is important for understanding land degradation's impact on women and children. Definition used by Shyamsundar (2002, p. 26) is "Distance walked by each household member to collect water and fuel per day X no. of household members X no. of days per year".

[14] Open access areas are highly vulnerable to experiencing rapid resource depletion. These areas are often lands owned by the state that has little capacity to monitor and enforce property rights. Poor squatter settlements on open access areas have difficulty and little incentive to organize collective action to manage natural resources in these areas (Lipper, 2002, p. 31).

[15] Needs to be used carefully (e.g., change in income may have been due to land degradation or that households have shifted towards another income generating activity).

[16] Adapted from Shyamsundar. Adapted defition from Shyamsundar (2002, p. 26) is change in "quantity of key minor forest produce consumed per season". Possible data source are population based surveys.

[17] Specific CPR indicators include: consensus-like and collective arrangement to use the CPR, sanctions for violators that use the CPR, existence of conflict-resolution means, and recognition by the government for community stakeholders to manage the CPR (Ekbom and Bojö, 1999, p. 11).

*Residents using traditional fuels[18]	*Marginal land*	SE
Existence of manure contracts between farmers and herders	*Marginal land*	SE
Manure contracts with transhumance herders or cattle owners	*Marginal land*	SE
(Seasonal) migration of men (excludes traditional patterns by nomadic groups)	*Employment*	SE
Changing roles of women and men	*Employment*	SE
Increase in non-farm employment for women and men	*Employment*	SE
Disempowement		
Presence of telephones	*Provision of information*	SE
Presence of internet access	*Provision of information*	SE
Price of transport	*Infrastructure*	SE
Transport problems due to bad roads	*Infrastructure*	SE
Distance to nearest market	*Infrastructure*	SE
Rural population access to safe water	*Infrastructure*	SE
Distance to market (input and output suppliers)	*Access to technology*	SE
Access to tools in market	*Access to technology*	SE
Availability/access to cart	*Access to technology*	SE
Farmers with access to irrigation	*Access to technology*	SE
Availability/access to cart	*Access to technology*	SE
*Cultural practices and spiritual beliefs and taboos that may be inhibiting use of technology and information to conserve land and soils	*Cultural practices*	SE
*Female and male roles in traditional land management and modern land management	*Cultural practices*	SE
*Change in women's indigenous knowledge associated with land management	*Provision of information*	SE
*Change in men's indigenous knowledge associated with land management	*Provision of information*	SE
*Change in indigenous knowledge on land management passed on to younger generations[19]	*Provision of information*	SE
Increased/reduced availability of tools in market	*Access to technology*	SE
*Availability of extension services/agricultural education	*Provision of information*	SE/I
*Frequency of extension services/agricultural education	*Provision of information*	SE/I
*Development of locally adapted demand based agricultural research and extension	*Provision of information*	SE/I
*Farmers using soil conservation/land management practices (e.g., use of less extensive tillage, terracing, mixed and perennial cropping, livestock rotation, and re-vegetation)	*Provision of information*	SE/I
Integration of farmer knowledge in tool development	*Access to technology*	SE
Increased/reduced availability of consumer goods and services	*Infrastructure*	SE

[18] Definition used by Shyamsundar (2002, p. 25) is "Proportion of population using firewood, dung and crop residues as primary fuel for cooking and heating".

[19] Shifting agricultural practices from traditional to modern techniques is furthermore making less relevant indigenous knowledge (on traditional agricultural practices) and its transfer to younger generations.

Presence of small-scale rural infrastructure projects	*Infrastructure*	SE	
Increase in farmer owned small cooperatives	*Infrastructure*	SE	
Installation of water pipes	*Infrastructure*	SE	

INSTITUTIONAL **Indicators at village and farmer level**	**Description**	**BP SE I**	**D P S I R**
Institutional indicators			
Presence/occurrence of religious/church/age group	*Institutional support*	I	D
Presence and number of farmer groups and related committees and associations	*Institutional support*	I	D
Female and male membership (as a percentage of village female and male population) in village committees/associations/groups	*Institutional support*	I	D
Number and role of NGOs	*Institutional support*	I	D, R
Replacement of rigid legal measures with local informal arrangements	*Participation/Transparency*	I	D, R
Presence of village-level dispute resolution mechanisms/institutions/groups	*Participation/Transparency*	I	D, R
Existence of legal aid for poor people	*Participation*	I	D, R
Evidence of consultation and public participation in permit, concession, or project approval during early stages	*Participation*	I	D, R
Evidence of consultation with women in project design and implementation	*Participation*	I	D, R
Evidence of off-site environmental costs where privatization exists	*Privatization*	I	I
Participation in farmer field day	*Institutional support*	I	R