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SUSTAINABLE LAND MANAGEMENT PRACTICES TO REVERSE LAND DEGRADATION IN LEBANON

by

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Sustainable land management practices to reverse land degradation in Lebanon

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1. Introduction

Lebanon is not only a small country but it is also a highly diversified area with several agro-ecological zones caused by different agro climatic conditions and complex orography. The rugged mountainous nature promotes natural soil erosion intensified by land cover and land use changes induced by human activities. Agriculture in this old civilization has been gradually replacing forest and fertile lands are increasingly replaced by human settlements. Overgrazing on marginal lands led to further deterioration of fragile ecosystems. Soils having relatively low organic matter content are susceptible to drought and not resilient to climate change. Water shortage promoted the use of brackish water in irrigation on coastal Lebanese areas. Groundwater salinity has been enhanced by excess pumping associated with reduced recharge. Secondary soil salinity is now observed not only in the dry semi arid north east Bekaa but also under greenhouses spread on the sub humid western mountains. Monoculture of vegetable crops in Bekaa plain associated with over fertilization and irrigation resulted in groundwater contamination with nitrates. Years of unregulated quarrying activities seriously affected biodiversity, vegetation cover and threaten water resources and public health. Unsustainable land management practices are exacerbated by the weakness or absence of adequate policies and regulations. Therefore, the aim of this paper is to review the state of the art on land degradation in Lebanon and to review local research conducted to stop and reverse negative trends through income generating activities to support the sustainable livelihood in rural areas.

2. Soil erosion mapping and mitigation

Soil erosion in Lebanon was assessed in many studies using remote sensing and GIS techniques. Maps showing vulnerability to erosion were based on relatively simple models which became gradually more and more complicated involving slope, lithology, climate, land cover, human factors (Figure 1) to produce actual soil erosion risks in a decision support system (BouKeir et al., 2001a, 2001b).

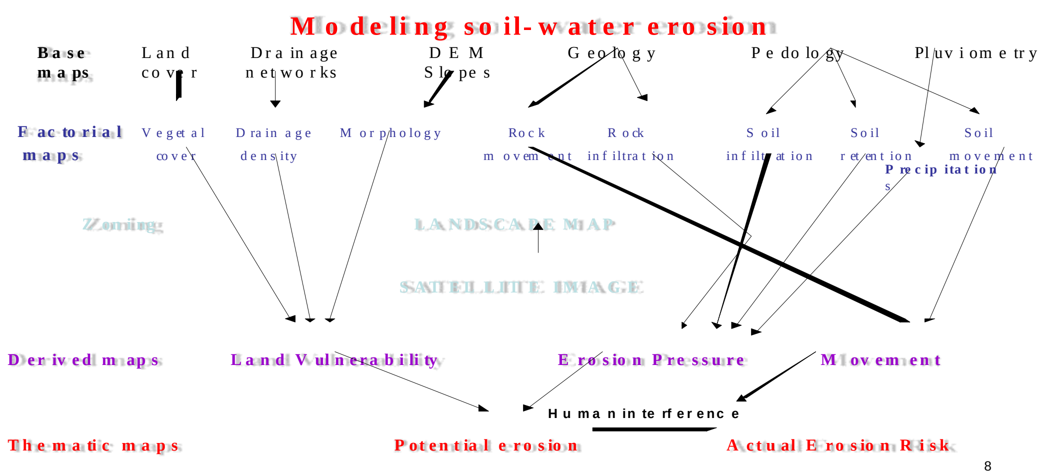

Figure 1. Model for the assessment of soil erosion (source: Boukeir et al., 2001a)

However, these assessments remain theoretical as long as they are highly technical and don't quantify the soil erosion rates (Figure 2). To improve the monitoring on of coastal land degradation, a semi-quantitative assessment of soil erosion was recently undertaken involving the descriptive mapping of land degradation (Figure 3a and Table 1).

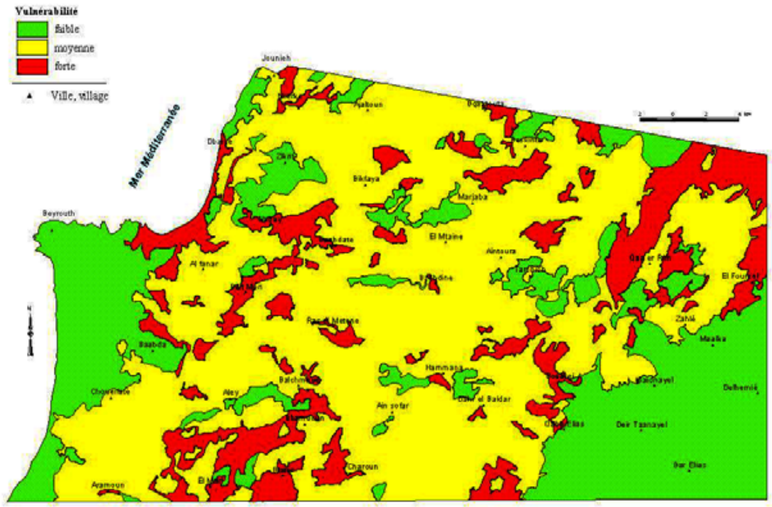

Figure 2. Generalized mapping of soil erosion in Central Mountainous Lebanese area (Source: Boukeir et al., 2001a).

Priority intervention areas were defined based on scoring of different physical and socio-economic factors (Figure 3b). A draft management plans with defined role of specific stakeholders (government bodies, NGOs, local population) and concrete tasks to reverse land degradation related to curative, preventive and remedial measures was elaborated (Khawlie et al., 2005).

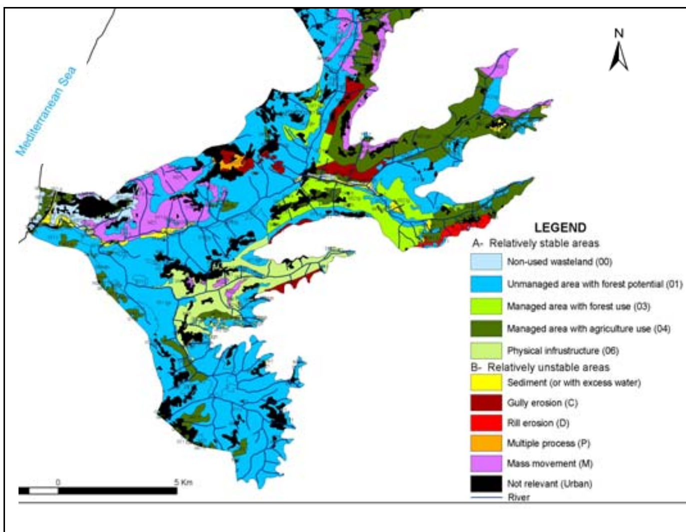

Figure 3a. Descriptive erosion mapping classifying stable and non stable areas and the types of instability factor

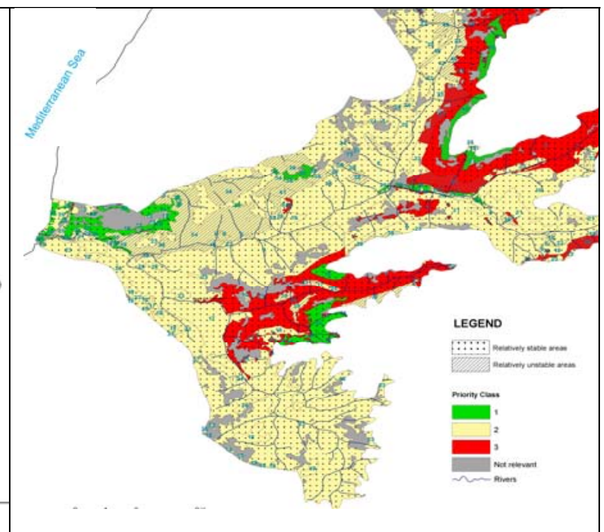

Figure 3b. Prioritization map of Damour Watershed

Table 1. Classification of stable (non erosion) and unstable (erosion affected) areas in Damour Watershed in georeferenced land polygons indicating the status of soil water erosion risk and expansion trends

Land Type	Erosion situation	Erosion risk/expansion trend	Area (Km^2)
Stable areas (75.3 %)	Non-used wasteland	Low to moderate	2,76
	Unmanaged areas with potential for forestry use only	Low to moderate	67,32
		High	0,79
	Managed areas with forestry use only	Low to moderate	1,10
		High	6,97
	Managed areas with agricultural use	No	4,93
		Low to moderate	18,81
	Rehabilitated areas	High	8,60
Unstable areas (13.9 %)	Sediment or excess water	Local	0,01
		Widespread	1,55
	Rill erosion	Widespread	1,36
	Localized gully erosion	Local	2,10
		Widespread	0,09
	Dominant gully erosion	Widespread	1,19
	Localized mass movement	Local	10,24
		Widespread	0,39
	Dominant mass movement	Local	0,92
		Widespread	0,96
	Localized associated processes	Local	1,68

3. Land cover/land use change

Land cover change analysis on the country level between 1963 and 1998 showed an expansion of barren an deserted land from 1076 km^2 to 4370 km^2 (Masri et al., 2002), with a significant recession in the vegetation cover by 32% for forest , 35% for citrus, 31% for olives, 82% for vineyards and 72% for fruit trees (Table 2). Changes were explained by socio-economic factors and climatic factors. Drought resistant trees like olives were less decreased than irrigated fruit trees and vineyards. The diminution of cultivated land was mainly related to market losses during the long lasting civil war1975-1990. Coastal subtropical crops were affected by chaotic urban expansion around major cities. The largest forest decrease was observed in the inland semi-arid zone of Bekaa plain due to natural and anthropogenic causes. There is a trend of decrease in precipitation, i.e. less or equal to 300 mm annually associated with socio-economic pressure overtaking local community caused by limited access to rangeland on the eastern mountain chain and unproductive lands in poor forest areas. On the contrary, more adequate climatic conditions coupled with better cultural and economic conditions in Mount Lebanon promoted the preservation and extension of forest areas.

Modeling multitemporal NDVI changes and comparing the vegetation index with outdoor grazing pattern revealed some improvement in the Mount Lebanon Range and decreasing trends of vegetation intensity in the Anti-Lebanon Range associated with a decrease in the vegetation cover at the end of spring beginning of summer associated with peak in outdoor grazing activities (Darwish and Faour, 2008). The soils of

Arsaal located in the semi arid Lebanese zone are characterized by low organic matter content of less than 1% (Darwish and Zurayk, 1997).

Table 2. Land Cover/use change in Lebanon between 1963 and 2000

Land cover/use	Area km^2		Change km^2	Change %
	1963	1998		
Forest	934.3	629.8	-304.5	-32.5
Citrus	268	174	-94	-35
Fruits	544.6	195.6	-349	-72
Olives	437	301	-136	-31
Vineyards	365.8	65.2	-300.6	-82
Barren or deserted	1076.6	4370	+3294	+306

Source: Masri et al., 2002.

Enriching the soil with carbon and nitrogen matches the millennium goals to develop marginal lands and promote carbon sequestration as a small contribution to face climate change. For this reason a new small grant UNDP project was launched in 2008 in Arsaal Jords by the DSA to introduce agro-pastoral system involving herders/farmers. The project aims at planting nitrogen fixing legume (vicia sativa) as green feeding intercropping system between the fruit trees, within the orchards where soil is traditionally left bare, with another double goal to protect lands from erosion and improve soil productivity. Farmers-herders are getting used to sustainably produce their own certified seeds on level large irrigated lands to secure seeds for the next season to be planted within their orchards to ensure the sustainability of this agro-pastoral system.

Stakeholders are encouraged to implement water harvesting practices for supplemental irrigation of feed crops and to introduce their flocks into their own lands for several days for onsite feeding on crop residues thus providing organic manure to improve the soil physico-chemical properties. Green forage must improve the quality of whole which is used to produce better quality local carpet by the local woman workshop. Simultaneously, improved carpet dye and design are provided and occupation is maintained with additional income to maintain rural population near own productive lands.
Sludge application was successfully tried even on the western mountain chain under olive orchards (Atallah et al., 2008). It had a beneficial effect on carbon and nitrogen enrichment of the soil. There are indications that treated and non treated sewage waters were successfully used in agroforestry as additional source of water rich in organic carbon and nutrients (Mouneimne et al., 2007).

On the other hand, forest fire recurring annually between midsummer and the beginning of winter is still one of the major threats of land cover in the western Lebanese mountain chain. A total number of 1413 forest fire events took place in 1997 alone. In 2008 Lebanon lost 4000 ha of forest land by fires. The reason behind the forest fire ignition can be attributed to the neglect and the mismanagement more than by well known edaphic factors such as aspect, NDVI, land cover, slope gradient and evapotranspiration (Masri, 1998). These factors were used for mapping of the forest fire prone areas in Lebanon (Masri et al., 2003). Results revealed that only 8 km^2 of broadleaved and coniferous, located in the southern exposure slope of western Mount Lebanon chain was identified as “very high and high” potential hazard. A total of 183 km^2 from the same green cover type, but located mostly on the northern aspect, was shown as “low to medium risk” category. Recent modeling of potential forest fire risks using RS and GIS (Faour et al., 2006) revealed the most vulnerable hot spots over Lebanon and results are used as a basis for the elaboration of the Lebanese national strategy to combat forest fires.

4. Groundwater salinization and irrigation using saline water

In the Lebanese coastal area the cultivation of protected crops is threatened by the seawater intrusion into ground water largely used for irrigation. Over-pumping and the reduction of natural recharge significantly contributed to the deterioration of well water quality (El Moujabber et al., 2002). Three year groundwater sampling from the southern coastal region and analyzes showed water salinity fluctuated around 3 dS m^{-1} and moderate to injurious contaminations as revealed by Simpson index (Cl/HCO3). Chloride concentrations in well water often exceeded 10 mM with a sodium/chloride ratios remaining <1, indicating the salts to be derived from the sea (El Moujabber et al., 2006).

Soil salinity inside the greenhouses reached 15-20 dS m^{-1} and sometimes 50 dS m^{-1}. Statistical data revealed the soil Cl to be responsible for at least 60% of soil salinity cases (Darwish et al., 2005). Irrigation using saline irrigation water and using Cl containing fertilizers poses problems to the sustainability of the greenhouse system on the Lebanese coastal area. Therefore, better land management practices oriented to hasten water and nutrients use efficiency was demonstrated growing protected tomato-jew's-mallow crops in sequence to phytoremediate built-up salts (Darwish et al., 2008a). Three levels of irrigation water salinity (1, 2.5 and 5 dS m^{-1}) were tested in two soil types with sandy and clay texture. Results showed that under sound management of water input, salinity had no obvious negative effect on tomato in the clay soil. The jew's mallow had a positive role in the remediation of soils with residual salts. Thus, replacing salt leaching practices and soil sterilization against nematodes in tomato monoculture by breaking the cycle during the summer through growing jew's mallow, or other salt accumulating crops, can provide feasible environmental and economic alternatives.

5. Impact of traditional land management practices in Central Bekaa

The contribution of major agro systems of the Central Bekaa to the soil-groundwater contamination with nitrates has been studied to assess the surplus of nitrogen input to the soil-groundwater system in the intensive vegetable production, fruit tree cultivation and field crop production. The analysis of soil and water samples showed high accumulation of nitrates in the soil towards the autumn (end of agricultural activities). Spring soil sampling revealed almost complete leaching of nitrates from the upper two meters soil depth (Darwish et al., 2007). Nitrates end up in the near surface groundwater (Figure 4).

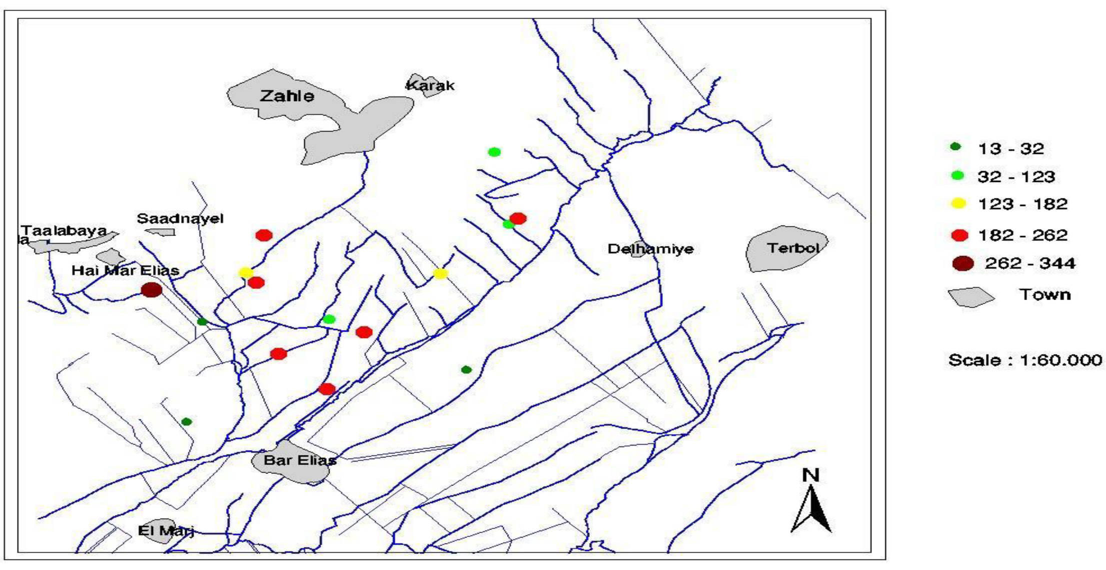

Figure 4. Nitrate concentration in the shallow groundwater table of the Central Bekaa Valley. (source: BGR, ACSAD, and CNRS-CRS, Arab-German Cooperation project 1997- 2003).

Even relatively deep groundwater was affected with highly soluble and leachable nitrates (Figure 5), showing concentration reaching 300-400 mgNO3 /l) at the lower parts of the plain The fact that NO3

concentration in the wells located on the plain edge shows normal NO3 concentration indicates the agricultural origin of nitrates in the well water.

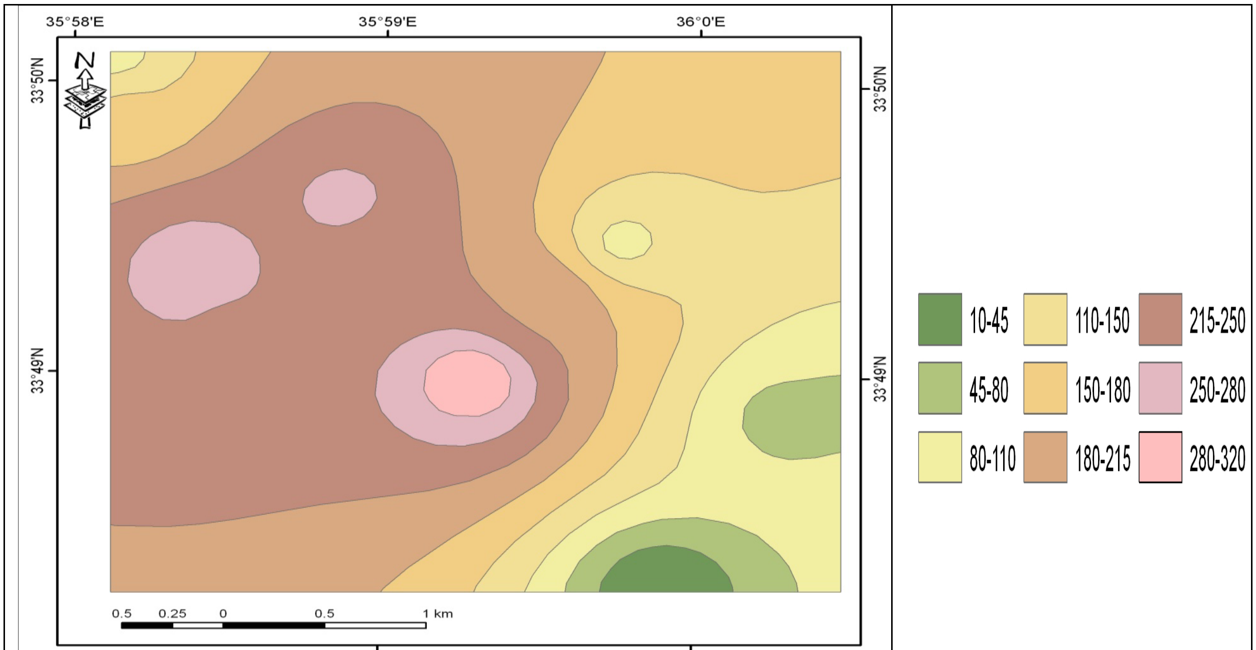

Figure 5. Accumulation of nitrates in deep groundwater of Ventral Bekaa (CNRS-UL-LIU project, Darwish et al., 2008b)

Nitrates accumulate in the soil as a result of overfertilization of field crops and monoculture vegetables. Using broadcast fertilizer application and traditional irrigation techniques like macro sprinklers contribute to nitrate movement to the subsoil and rainfall complete the picture of further leaching to the groundwater (Darwish et al., 2003). Fertigation as a modern and more efficient irrigation technique using drip system brings water and fertilizers to the root zone with no risks of soil and groundwater contamination (Table 3). Currently, both good and bad agricultural practices with direct farmer's participation are being emphasized through demonstration plot experiments on the farmer's field to show the possibility of the reliance on nitrogen provided by the soil and irrigation water pools.

Table 5. Average nitrate leaching as affected by the farmer practice of N fertilizer input and irrigation techniques

N input (Kg/ha/year)	Irrigation technique	Concentration of NO3 (mg/l) at different soil depth of potato plots			
		40 cm	60 cm	80 cm	100 cm
500	Macro sprinklers	114	125	227	307
300	Macro sprinklers	132	93	165	166
300	Drip	97	55	Not found	Not found

(Source: Darwish et al., 2008c)

6. Impact of quarrying activities on natural resources and rehabilitation of quarries into intial landcover or alternative uses

Institutional weakness, absence of policy for integrated land resources management and years of unregulated open mining activity have left hundreds of abandoned quarries across Lebanon (Figure 6). Spontaneous restoration is slow and often ineffective in Mediterranean ecosystems and active site restoration is needed to alleviate, reduce or counter the negative environmental impact of quarries. Satellite images showed that over less than ten years, quarries increased from 784 in 1993 to 1278 in 2005 (almost one quarry for each 8 km^2 over the Lebanese territory).

Figure 6. Impact of quarries on land cover in Lebanon

Quarries expansion occurred mainly on forest areas and mountainous agricultural systems including olives and grape vines and irrigated zones (Figure 7). Satellite data revealed that 78.5% of the quarries are located within fragile environment (sloping lands and steep slopes); 87% of the quarries represent potential hazards for surface and groundwater quality because they are located on medium to high infiltration bedrocks. With regards to landuse, around 2300 ha of fertile soils were lost to quarrying activities.

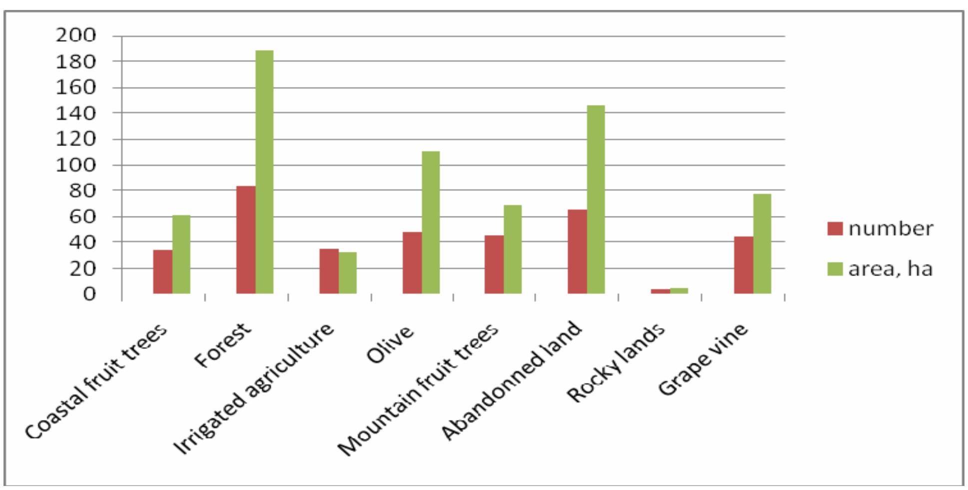

Figure 7. Quarries expansion area between 1993 and 2005 on corresponding land cover and land **use**

Limited national resources available for reclamation must be targeted toward those quarries where the likelihood of successful reclamation, and thus the likelihood for mitigation of negative environmental impacts, is the greatest. To facilitate such decision making we developed a GIS based model that utilizes geomorphological and pedoclimatic characteristics of the site, including precipitation, slope gradient, slope aspect, rock infiltration, catchments' area, the availability of soil

material and soil texture to assess probability of reclamation success (Darwish et al., 2008d). Each abandoned quarry was categorized into specific class with respect to surrounding native vegetation, rainfall range and slope gradient. Deserted quarries were assessed for suitability for vegetation establishment and/or water harvesting.

Potential revegetation success was strongly linked to slope aspect where southern facing slopes especially in semi-arid areas with annual rainfall below 600mm, were given lower prospects of success with relation to spontaneous revegetation processes. The quantity and quality of soil material adjacent to quarries was included in the vegetation model to evaluate the possibility of providing sufficient mineral substrate from neighboring areas with deep soils possessing good physico-chemical properties for plant establishment and survival. All attributes in the vegetation recovery model were assigned a weighted numeric score which were summed to provide a relative ranking of all quarries. These were then separated into four classes of likely revegetation success (Figure 8). In addition, water harvesting potential was assessed based on catchment area above the quarry and rock permeability in the quarry. The priority for reclamation was based on the comparison of vegetation success and suitability for water harvesting. The results of this model can be used to facilitate decision making concerning priority selection of sites for reclamation efforts, reclamation strategies to be attempted and possible alternative post-reclamation land use.

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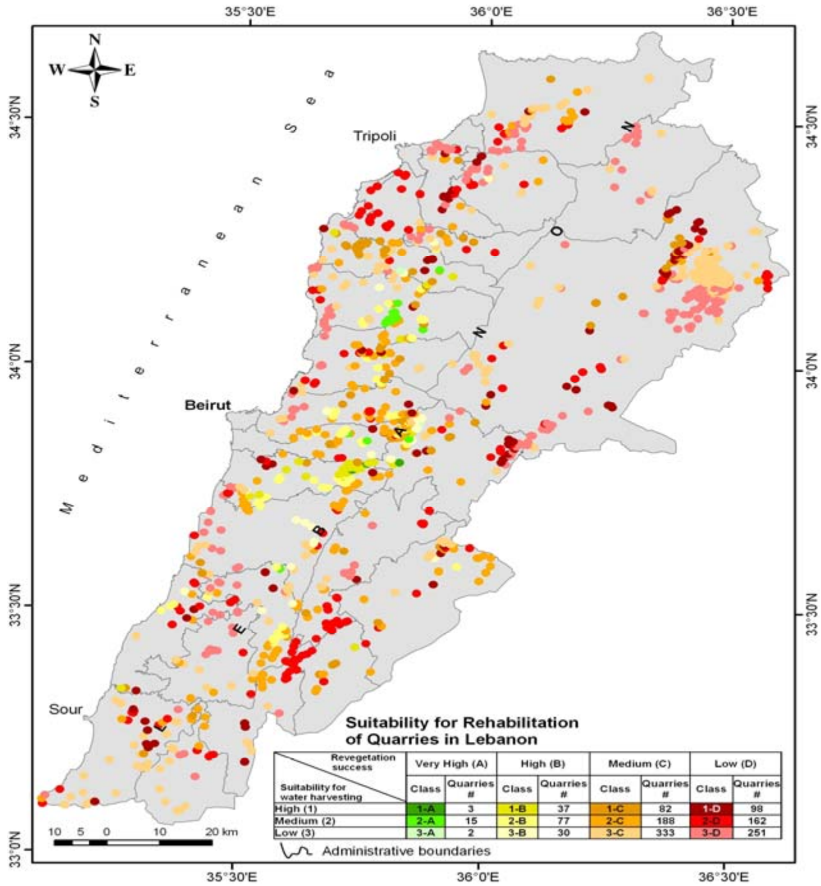

Figure 8. Combined model output of quarry suitability for rehabilitation in Lebanon either into initial land cover and/or water harvesting.

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