RANGELAND DEGRADATION IN TWO WATERSHEDS OF LEBANON

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ABSTRACT

A complex and rugged nature characterizes the Lebanese mountains.The climatic pattern prevailing in the country, deforestation and man made erosion caused increased rangeland degradation. The purpose of this study was to monitor two contrasting watersheds, representing the Lebanese agro-ecological zones, to analyze the vegetation dynamics and trace the state of rangeland degradation. The Kfarselouane (205 km^2) and Aarsal (316.7 km^2) watersheds are located in the Lebanon and Anti-Lebanon mountain chain and characterized by sub humid and semi-arid climate respectively.

Using multitemporal spot vegetation images between 1999 and 2005 to analyze the normalized differential vegetation index (NDVI) revealed some improvement of the vegetation cover over recent years in Kfaselouane with a steady state in Aarsal. The NDVI trend curve inclines in spring and declines in summer and fall. Judging by the time scale amplitude change and highest magnitude between the peak and lower NDVI level in Aarsal, an increased vulnerability to drought is observed in the dry Lebanese areas. Comparing land cover/use in Aarsal area between 1962 and 2000 using aerial photos and large resolution Indian satellite images (IRS) showed wood fragmentation and slight increase of the degenerated forest cover from 1108 ha to 1168 ha. Landuse change was accompanied by a simultaneous increase of cultivated lands (mostly fruit trees) from 932 ha to 4878 ha with absence of soil conservation and water harvesting practices. On the contrary, grasslands decreased from 29581 ha to 25000 ha. In Kfarselouane, the area of grassland was invaded by forestland where rangeland decreased from 8073 ha to 3568 ha and woodland increased from 5766 ha to 11800 ha. Forest expansion occurred even at the account of unproductive land which decreased from 2668 ha to 248 ha, while cultivated lands did not reveal any substantial change. Based on animals' seasonal feeding pattern, a mismatch between land carrying capacity and grazing pressure is observed indicating the necessity to develop intermixed irrigated pasture-fruit tree production for supplemental feeding during the dry months.

Keywords: land use change, grassland management, overgrazing, land degradation

INTRODUCTION

Land resources in Lebanon have been continuously subjected to increasing human pressures since the old times. The dominance of bare lands with shallow soils points to processes of severe erosion and land degradation (Darwish *et al*., 2003). Several natural and human-induced factors contributed to that degradation in the country.

Analysis of digital elevation model (DEM) shows that 64% of the Lebanese territory has a complex landform with sloping and rugged lands, implying that steep slopes are a major physical factor enhancing soil erosion by water. The torrential rainfall causes flash floods and erosion sometimes leading to mass movements due to poor drainage and weak lithology. Among the oldest direct human-induced factors are deforestation and degradation of vegetative cover in the mountains. Forest fires and chaotic urban sprawl amplify the negative impact of deforestation and erosion notably on the dynamics of rangeland.

About 4.5 millions km^2 of lands in the Near East region are classified as permanent pasture (Harris, 2000). Most of these rangelands are distributed in the semi-arid and arid areas with a non-uniform rainfall distribution and amount. The alternation of moist and long dry periods in this area predetermines the productivity and carrying capacity of rangelands. Poor soil fertility aggravates the impact of the socio-economic factor which can be resumed by poverty, market conditions and land tenure (inheritance, land fragmentation) and the absence of policy or weak implementation of legislation regulating rangeland management.

Grazing rights and practices vary from region to region and both together with the type of ownership affect the sustainability of grazing lands not only in the grasslands but also in the forest and fresh cut areas. In this regard, structural rehabilitation and maintenance measures and the indigenous traditions are of equivalent importance for the conservation of green pasture (Zurayk & El Moubayed, 1994). Overgrazing and the misuse of rangelands cause disappearance of useful species and dominance of unpalatable plants. Due to the erosion of genetic resources of forage plants, West Asia is loosing important species like *Atriplex halimus, Atriplex leucoclada* and *Haloxylon persicum* (Hamadeh, 2005).

Landscape is characterized by a complex and rugged nature which multiplies the vulnerability of Lebanese mountains to degradation if land cover is significantly recessed. Vegetation tends to absorb strongly the red wavelengths of sunlight and reflect in the near-infrared wavelengths. The normalized differential vegetation index (NDVI) is the most common measure of physiological and biochemical plant development. Accordingly, this work aims at assessing the impact of various physical (location, landform, rainfall amount) and human factors on the degradation of rangelands in the Lebanese mountains using remote sensing techniques.

MATERIAL AND METHODS

Lebanon consists of two parallel mountain chains, the western and eastern, separated by the Bekaa plain. The climate is in general Mediterranean. The country represents a series of geomorphologic units ranging from level quaternary plains to sloping and steep mountains with alternating soft marl and hard limestone rocks. Basalt and sandstone are intruded here and there. More than 60% of the Lebanese area is slopping and steep lands which increase land vulnerability to degradation if land cover is abused.

For the purpose of this study two mountainous pilot areas with contrasting climatic conditions were chosen. The first case is Kfarselouane subwatershed with an area of 205 km^2 located on the western mountain chain and the second is Aarsal subwatershed with an area of 316.7 km^2 spread on the Anti-Lebanon mountain chain in Northeast Bekaa (Figure 1).

The work uses the vegetation reflection index (NDVI) as a tool to monitor trend lines and land cover/use change as indicators to elaborate draft plans for combating desertification in Aarsal representing the semi-arid and Kfarselouane representing the subhumid agro-ecological zone. Kfarselouane is characterized by an average annual precipitation between 800 and 1400 mm through the subwatershed transect. Aarsal subwatershed is distinguished by an average annual rainfall between 300 mm at the level of Aarsal village and 600 mm in the elevated area. In both areas a long dry season (up to seven months) with no rainfall is common.

Figure 1. Location of the Kfarselouane (1) and Aarsal subwatersheds (2).

Land cover map of 1962 was derived from topographic maps of Lebanon scale 1:20000 and aerial photos using visual interpretation method. Land cover map 2000 was derived from pan-sharpen satellite image (5m resolution) using landsat and IRS-1C (Indian satellite), adopting Corrine nomenclature, using visual interpretation. Both legends were adapted for comparison. NDVI was produced using Spot multitemporal (10 day resolution) and 1 km x 1 km spatial resolution from January 1999 until September 2005. Time series NDVI model is separated into linear trends and error. The equation of the trend is:

$$NDVI_{(t)} = \alpha + \beta t + \varepsilon$$

Where t is time; α, ß are constants of the linear model and ε is noise.
ß represents strength and direction of the trend line fitting. The model was implemented into ERDAS software.

Variable soil types like Fluvisols, Cambisols, Luvisols, Regosols, Leptosols, Anthrosols, and Calcisols are present in the study areas, with a dominance of shallow and aridic soils in the Aarsal subwatershed.

RESULTS AND DISCUSSION

According to the available information, the area of irrigated lands in Lebanon increased from 64,100 ha in 1973 (Lebanese Statistics, 1973) to 100,000 ha recently (MoA/FAO, 2004), with 40% of lands located in the Bekaa Valley. Irrigable lands might reach 167.000 ha in 2015 (Comair, 2005). According to these results based on land capability classification, the area of marginal land which can be used for grazing and reforestation is 388200 ha. The area of non arable lands exceeds 165000 ha. However, these rocky lands are usually not continuous, and certain soil material is usually deposited between the rock outcrops supporting sparse vegetation. Therefore, 10 to 20% of this area can be considered as rangeland. This applies notably to the mountain slopes where animal can spend at least three to six months depending on altitude, climatic conditions and carrying capacity of the lands. Therefore, not more than 400000 ha can be considered as rangelands, which are equivalent to 38% compared to previous estimation of 52% (FAO, 1980) of the total Lebanese area. This means two things:

1. a reduction in the available rangeland area due to erosion, agricultural expansion and urbanization
2. Considering the poor productivity of rangelands, the carrying capacity of rangeland in Lebanon does not exceed 800000 small ruminant heads.

Monitoring of the vegetation index in the study areas

The multi temporal 7-year analysis of NDVI over the study areas from 1999 until 2005 revealed a general trend of amelioration in the green cover in Kfarselouane with a steady state in Aarsal (Figure 2). However, the poor vegetation cover in Aarsal was observed despite the decreased amplitude and increased frequency of the NDVI index over the alternation of dry and wet seasons, indicating the probable impact of seasonal drought in dry Lebanese Mediterranean areas.

Analyzing a randomly chosen one year (2002) value of NDVI in the pilot areas showed a different peak pattern which started in February in Kfarselouane reaching the maximum range in March April (Figure 3). This peak was shifted in Aarsal and started in March reaching maximum value in May-June. Similar changes can be explained by the nature of vegetation cover. Such trend lines pattern indicates that reported flock's migration to the wintering sites and spring grazing (Hamadeh, 2005) are appropriate but the issue of overgrazing in summer still unsolved. This is because the practiced grazing calendar of small ruminants, *i.e*., the % reliance on outdoor animal feeding, has more or less constant trend line during the summer and fall periods. It fluctuates around 90% while the green vegetation cover in both areas declines during this time (Figure 3). During this period overgrazing probably exceeded the normal carrying capacity of the land.

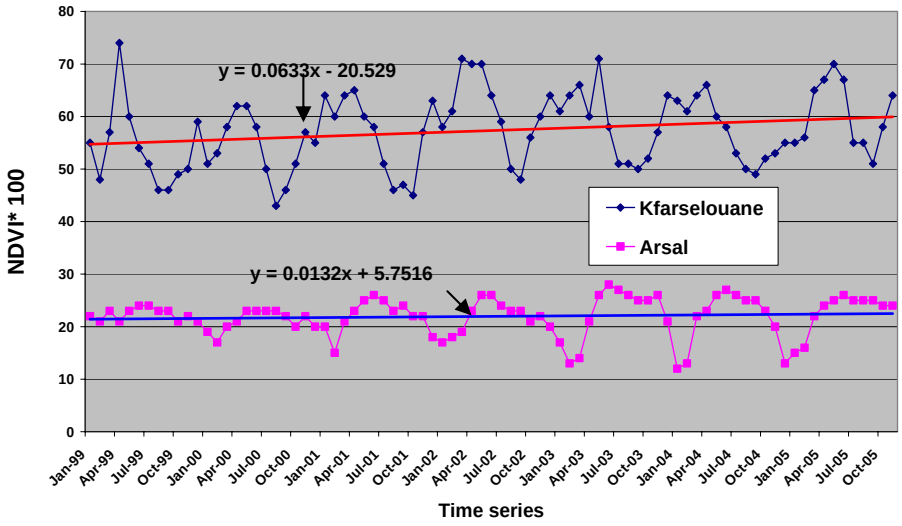


Figure 2. Long term time series analysis of NDVI in Kfarselouane and Aarsal.

Verification of NDVI trend lines and land cover/use changes in the study areas

With the change of Kfarselouane's people occupation from forest-mulberry cultivation to wheat cultivation during the 1920s, large areas for grazing on crop residues were available for animal production (Zurayk & El Mouybayed, 1994). However, after the World War II, landuse changed from wheat to vine and apple cultivation. The breakdown of traditional grazing practices and reliance on fruit trees as alternative source of income caused the disappearance of large grasslands and vine cultivation areas.

Comparing land cover/use change in Aarsal area between 1962 and 2000 using aerial photos and large resolution satellite images from the Indian Remote Sensing (IRS) showed a change in the spatial distribution of woodlands, fragmentation and slight increase of the degenerated forest cover from 1108 ha to 1168 ha (Table 2), with a simultaneous increase of cultivated lands (mostly fruit trees) from 932 ha to 4878 ha respectively (Figure 4). Quarries expanded over 463 ha of mountainous lands. Consequently, grasslands decreased from 29581 ha to 25000 ha.

For the same period, the area of grassland in Kfarselouane was invaded by forestland where rangeland decreased from 8073 ha to 3568 ha and woodland increased from 5766 ha to 11800 ha respectively. The forest expansion occurred even at the account of unproductive land which decreased from 2668 ha to 248 ha, while cultivated lands did not reveal any substantial change.

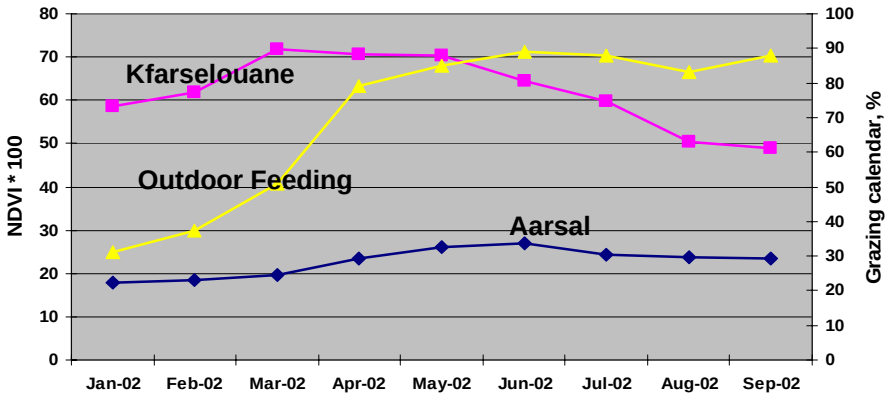


Figure 3. Seasonal vegetation index of Kfarselouane and Aarsal subwatersheds versus the practiced feeding calendar.

Grazing practices

Livestock production is an integral part of dryland management in Lebanon with an increased number of local breeds of sheep and goats adapted to scarce vegetation (Awassi and Baladi) from 500,000 in the 70s to 700,000 in the 90s (Hamadeh, 2005). The expansion of cultivated lands and reduction of rangeland, associated with the low productivity of rangelands, lead to overstocking and overgrazing of fragile lands. 75% of annual diet is provided through permanent or seasonal migratory from rangeland grazing and partial lease of agricultural lands in Bekaa. Up to 40% of this grazing pattern focuses on common lands which provide 30% of animal diet year round. Aarsal is identified as a transfer point for the winter migration of more than 30000 heads towards the semi-arid Lebanese or Syrian areas. Meanwhile, Kfarselouane and its surrounding is the transfer point for less than 5000 heads which in semi-nomadic way cross the area for wintering on the coastal area. But, in summer a large undetermined number of flocks visit Kfarselouane for grazing.

Managing the carrying capacity of Lebanese rangelands for small ruminants, which was estimated to be below 2 head/ha, showed that the carrying capacity is exceeded by 30% on both Mount Lebanon and Anti-Lebanon slopes (Hamadeh, 2005). This and other landuse constraints in Aarsal like expanding the cultivated area to the rangelands and the absence of protected zones for biodiversity conservation resulted in the fragmentation of pastoral lands, loss of natural habitat and possible erosion of wild crop relatives.

Aarsal in general suffers from higher rate of rangeland degradation due to overgrazing, quarrying activities, wood cutting, and land reclamation for "extensive agriculture" because land is not used according to its capability and suitability. The latest factor is related to low farmers skills and the absence of soil conservation measures, like the construction of terraces, traditionally found on the western mountain slopes. Anti-Lebanon

had been traditionally used for grazing. Recently, cultivating rainfed fruit trees became the major source of income in Aarsal. On the contrary, in Kfarselouane the privately owned lands is 47% and the communal land is leased to the stakeholders. Kfarselouane land has a protected forest area where animals are not allowed to graze within the 8 years after controlled wood cutting. Dry herbs and plant residues which can multiply the risks of forest fires are grazed in summer.

TABLE 2

Detailed Land Cover/Use Change in Kfarselouane and Aarsal (Ha)

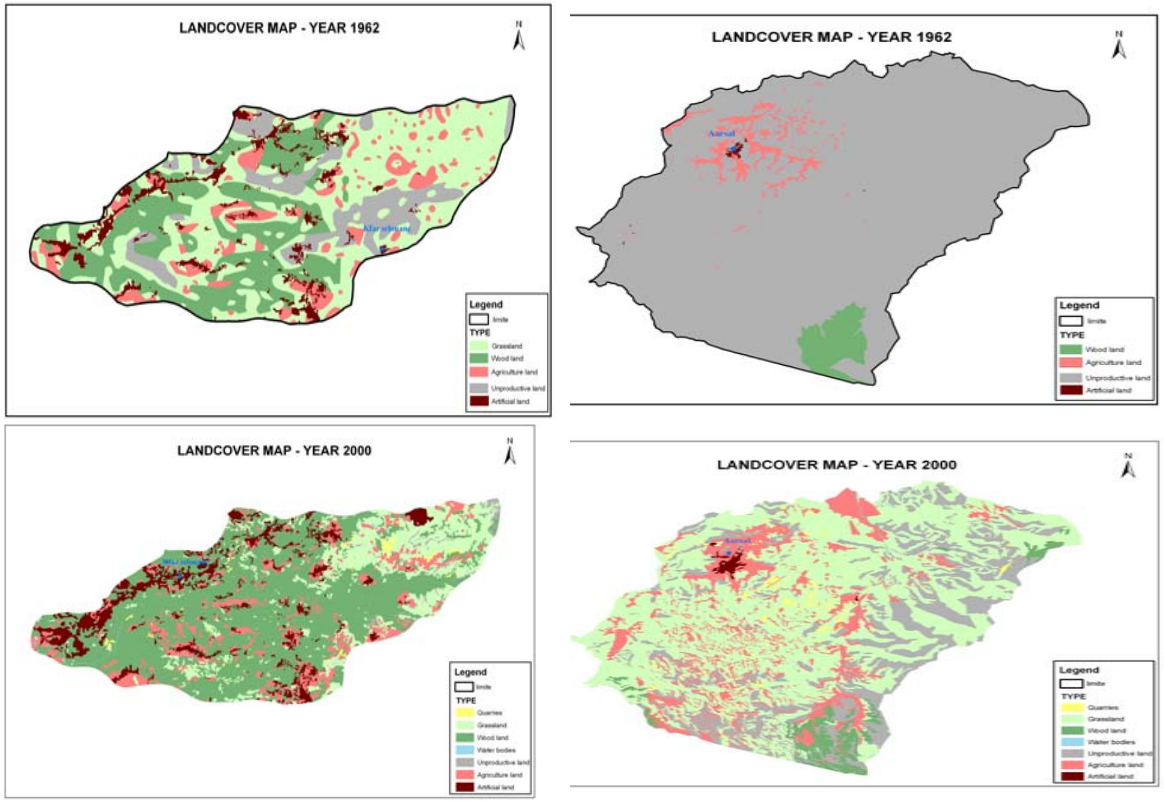
TYPE	Kfarselouane		Aarsal	
	1962	2000	1962	2000
Agriculture land	2592.64	2568.53	932.68	4878.82
Grassland	8073.51	3568.10	Not identified	18062.15
Unproductive land	2667.87	248.46	29581.74	6949.34
Wood land	5765.95	11799.79	1108.30	1168.38
Artificial land	1405.04	2099.12	44.96	144.91
Quarries	0.00	182.54	0.00	463.61
Water bodies	0.00	38.48	0.00	0.47
Total	20505.02	20505.02	31667.67	31667.67

Response to reverse land degradation: legislation and socio-economic factors

To enhance the protection of fire prone areas, the ministerial decision 181/98 introduced a five year ban on grazing on public land after fires to enhance land cover recovery and protect soil against erosion. However, the law 558/96 protected the forests and allowed just the pruning of fruiting pine. But, the rural community pressure and studies showed increased fire hazards under prevailing protection system and proved the advantage of forest conservation by sustainable management and interaction of local community with the forest, which is a part of their livelihood (Masri *et al*., 2006). Forests provide the local stakeholders an additional income by exploiting the medicinal and aromatic plants, honey charcoal production and controlled grazing.

Internal migration did not play any important role in rangeland degradation in both study areas. But a progressing loss of interest to agriculture among young population was observed in Kfarselouane and considered as responsible for the breakdown of traditional land conservation practices (Zurayk & El Moubayed, 1994). This can lead to the collapse of terraces in the upper Kfarselouane subwatershed and can negatively affect the natural balance of grassland ecosystem. The grassland area, however, was more affected by the expansion of forest area and related mismanagement.

Reduced farmers' income from irrigated fruit trees production pushed local stakeholders to lease their open grasslands for grazing to those herders who pay more money regardless of the number of grazing animals. Water harvesting practices contributed so far to



Kfarselouane Aarsal

Figure 4. Temporal land cover/use change.

prevent flush flood in Kfarselouane, while this practice is absent in Aarsal. Inundation of low lands is frequently observed in Aarsal subwatershed due to the absence of real water harvesting and soil conservation measures. This increases the risks of desertification resulting in deteriorated springs, soil erosion, mass movements, ecological imbalances, deforestation and reduced nutrients to plants (Khawlie, 2001). Analysis of NDVI in the Bekaa Valley showed a 40% decrease in the natural vegetation cover between 1987 and 2000 within a small area (Jomaa & Khawlie, 2002). Rangeland in the Bekaa dropped from 142000 ha to 50000 ha with a substantial increase of irrigated lands from 26000 ha to 55000 ha (Lebanese Statistics, 1973; MoA/FAO, 2004). Similar trend was noticed in Mount Lebanon and other Lebanese cazas. These observations showed that the abandonment of rainfed wheat cultivation on mountainous slopes which used to be covered by primitive terraces deprived the small ruminant flocks from a valuable source of grazing on crop residue in summer time. For this reason more pressure was put on forest lands for grazing beside other existing natural and manmade hazards.

The national action plan to combat desertification (NAP, 2002) defined the causes and impacts of land degradation in Lebanon and laid the basic outlines for a national action program to mitigate and reverse land degradation. However, this action program needs further development and support to draw and implement the detailed rehabilitation projects involving the local communities in income generating activities.

CONCLUSION

While forest in Kfarselouane is protected it is not the case in Aarsal. Despite the minor role of internal migration in both study areas, young population in Kfarselouane is increasingly loosing interest in agriculture while the population of Aarsal expands the cultivation of rainfed fruit trees without terracing, appropriate agricultural practices or effective water harvesting. Land abandonment put increased pressure on Kfarselouane lands which were characterized by the prevalence of soil conservation and water harvesting practices. Recent changes in land cover/use led to the expansion of forest land in Kfarselouane and fruit trees in Aarsal both at the expense of grasslands. Monitoring the NDVI changes over time revealed higher frequency and reduced amplitude of the peak of green cover during the spring time and base line during the dry summer months. Comparing the trend lines of the vegetation index with the grazing pattern revealed an overgrazing of mountain rangelands. A controlled grazing within silvi-pastural and silvi-horticultural systems can sustain the interest of new generation to implement and sustain land conservation measures. Improving the income of local population from agriculture, rainwater harvesting and the production of export fruits can enhance population involvement in rangeland management as a part of the ecosystem.

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