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# Land degradation in north-western Jordan: causes and processes

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Improper farming practices, overgrazing, the conversion of rangelands to croplands in marginal areas and uncontrolled expansion of urban and rural settlement at the cost of cultivable land are among the major causes of land degradation in north-western Jordan. The purpose of this study was to discuss the major causes of land degradation in the area.

Six sites receiving different amounts of annual precipitation and with different vegetation types were selected to represent the major agricultural areas in north-western Jordan. The major soil properties that can be linked to land degradation were studied.

Desertification in north-western Jordan is taking place through loss of soil fertility and productivity, overgrazing and water and wind erosion. Erosion by wind and water is considered the major cause of land degradation in the area. The soils contain little organic matter and their alkaline reactions reduce the availability of phosphorous and macronutrients and consequently lead to very low crop yields.



**Keywords:** desertification; soil erosion; arid climate; marginal lands

## Introduction

Desertification is defined as 'land degradation in the arid, semi-arid and dry subhumid regions resulting from various factors, including climatic variations and human activities' (UNEP, 1994). Rainfall patterns, soil morphological and pedological properties, vegetation and land use determine the extent of land degradation. Leading causes of land degradation in north-western Jordan are improper farming practices (such as failure to use contour ploughing or overcultivating the land), overgrazing and the conversion of rangelands to croplands in marginal areas where rainfall is not enough to support cropping in the long-term, and uncontrolled expansion of urban and rural settlement at the cost of cultivable land. The existing ecosystems of north-western Jordan are fragile and prone to deterioration. This results in lesser vegetative cover and eventually loss of the fertile topsoil. This makes the soil incapable of supporting plant growth and thus more susceptible to degradation.

Desertification is intense in the steppe zone, which serves as the desert forefront. Different investigations suggested that climate in this zone had changed several times during the Quaternary. The last of these changes was the present aridic climate (Rognon & Williams, 1977). The last episode of climatic changes is responsible for the development of unfavourable soil properties that accelerated the degradation of many plant species. Coupled with the effect of continuing drought incident, removal of plant cover was greatly enhanced (Taimeh, 1991).

The purpose of this study was to discuss the major causes of land degradation in north-western Jordan.

## Materials and methods

Six sites receiving different amount of annual rainfall were selected to represent the major agricultural areas in north-western Jordan. The location of these sites is shown in Fig. 1.

The climate of the study area is of Mediterranean type with an average annual precipitation ranging between 200 and 500 mm (Meteorological Department, 1988). The rainy season extends from November to March. This climatic region is in the

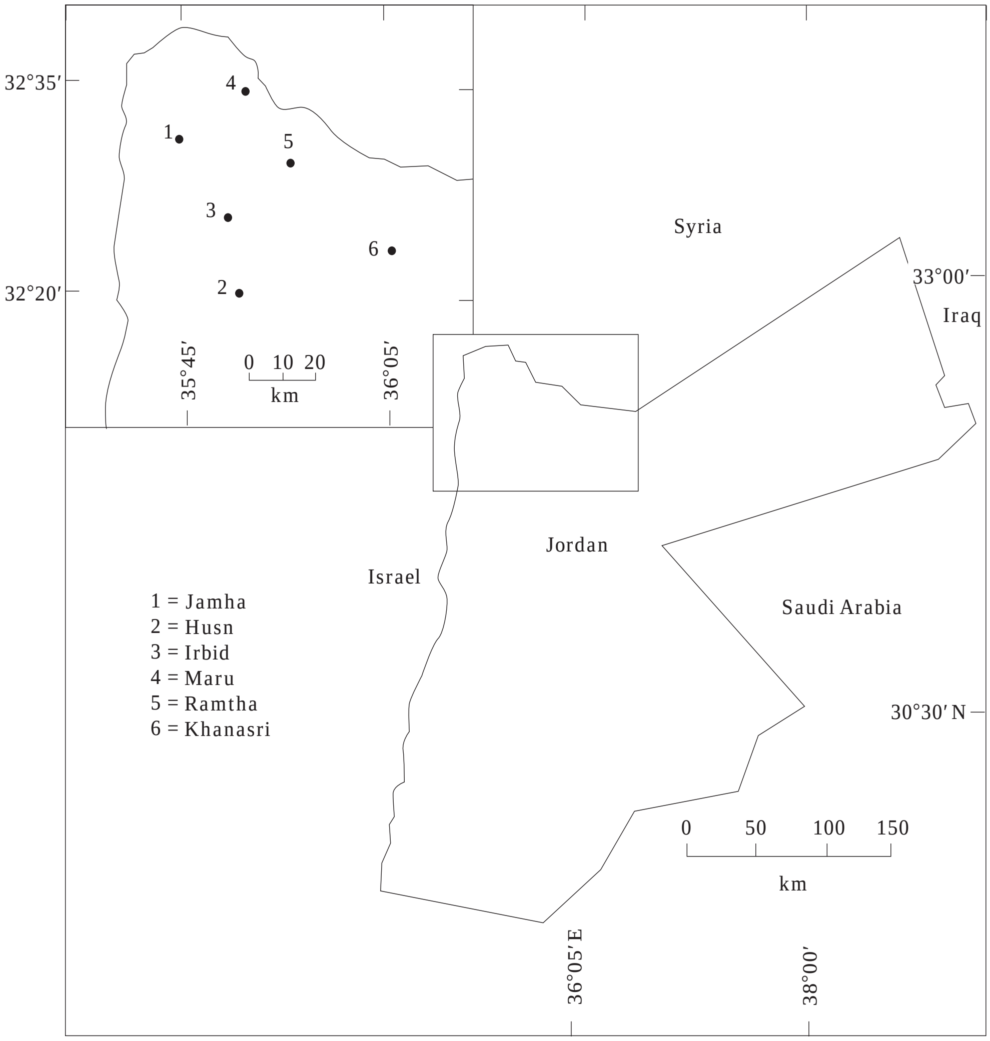


**Figure 1.** Location of the study sites.

500–600 m elevation zone above sea level and is considered the major farming area in north-western Jordan. Mean winter temperature ranges from 5 to 9°C and mean summer temperature range from 22 to 29°C. The main characteristics of each site are presented in Table 1.

Native vegetation at sites 5 and 6 (Fig. 1) is *Poa sinaica*, *Carex pachyslis*, and associations of *Artemisia herba-alba* and *Salsola rigida* with grasses such as *Dactylis glomerata*, *Hordeum bulbosum* and *Phalaris paradoxa*. Native vegetation at sites 1, 2, 3 and 4 consists of *Anabasia articulata* and *Seidlitzia rosmarinifolia*. Other shrubs include *Zilla spinosa* and *Asphodeline lutea*.

Soil samples (0–30 cm depth) were randomly collected from the study sites to represent the soils of the area. Non-representative soils were excluded from the sampling process. The bulk soil samples were air-dried, crushed with a mortar and pestle and sieved to remove coarse fragments. Particle-size distribution was determined by the hydrometer method (Gee & Bauder, 1986). Soil pH was measured on 1:1 soil:water suspensions (Mclean, 1982); soluble salts were determined by measuring electrical conductivity of 1:1 soil:water extracts (Rhoades, 1982); organic matter was determined using the Walkley-Black method (Nelson & Sommers, 1982); available phosphorous was measured using the procedure of Watanabe & Olsen (1965); total nitrogen was determined using the Kjeldahl method (Bremmer & Mulvaney, 1982); and calcium carbonate equivalent values were obtained using the acid neutralization method (Richards, 1954).

## Results and discussion

### *Soil pH, electrical conductivity and calcium carbonate*

Soil pH values increased from 7·5 at site 1 to 8·2 at site 2 (Table 2). However, at site 6 the pH values were lower than those of other sites receiving higher precipitation. This is attributed to the higher EC value (1·00 $dSm^{-1}$) at site 6 (Table 2). The similarity in pH values at the different study sites indicates the slow rate of weathering and soil development in these arid and semi-arid regions (Gharaee & Mahjoory, 1984). This slow weathering process is considered a cause of land degradation in the study area.

Salinity is not a common problem in the study area, as indicated by the EC values for the studied soils (Table 2).

One of the most common characteristics of the soils in the study area is the presence of horizons of carbonate accumulation (Table 2). The correlation analysis indicated that carbonate content is inversely correlated with the amount of precipitation ($r = -0{\cdot}86$); it increased from 4·0% to 24·2% at sites 1 and 6, respectively. The calcareous nature of these soils, which causes problems in nutrients availability to plants, is another cause for land degradation in the study area.

**Table 1.** *Main characteristics of the studied sites*

| Site | Precipitation (mm) | Land use | Human impact | Landscape position | Temperature regime | Moisture regime |
|---|---|---|---|---|---|---|
| 1 Jamha | 500 | Cereal | Ploughing | Middle slope | Thermic | Xeric |
| 2 Husn | 300 | Tobacco | Clearing | Flat | Thermic | Xeric |
| 3 Irbid | 450 | Olives | Ploughing | Middle slope | Thermic | Xeric |
| 4 Maru | 350 | Cereal | Ploughing | Flat | Thermic | Xeric |
| 5 Ramtha | 300 | Cereal | Irrigation | Lower slope | Thermic | Xeric-Aridic |
| 6 Khanasri | 200 | Grazing | Compaction | Lower slope | Thermic | Xeric-Aridic |

### *Organic matter, N and P*

Organic matter content was generally low and increased with the amount of precipitation (Table 2). Organic matter content of sites 1, 3 and 6 reached 1% for the surface horizons, meeting the requirement of the mollic epipedon. However, they were not classified as mollic epipedons because of the lack of the thick dark colour or soft consistency (Soil Survey Staff, 1975). Generally, organic matter content increased westward as the clay content and vegetative cover increased. Site 6 had higher organic matter, although clay content is lower than that at sites 2 and 4. This is because of the convex surface and surface cracks (fissures) of site 6 which helped higher infiltration and resulted in more vegetation due to increases local moisture levels (Honeycutt *et al.*, 1990). The low organic matter content of the studied soils contributed to land degradation. Total nitrogen and extractable phosphorous were low (Table 2). N was as low as 0·02% at site 6 which receives the lowest amount of precipitation. Phosphorus levels were generally low at all studied sites. The low phosphorous levels are attributed to the high pH values. The C/N ratio (Table 2) at site 6 was 55. This higher ratio compared to the other studied sites could be due to low rainfall at site 6. This site is located in an arid area where drought hinders organic residue decomposition.

Silt content increased from 32·5% at site 1 to 61·0% at site 5 (Table 2). This increase is attributed to aeolian additions (Gile, 1970; Gharaee & Mahjoory, 1984). An increase of silt content lead to unfavourable soil properties (structure and crusting) and eventually unfavourable plant growth conditions (Bresson, 1995). Consequently, vegetative cover will be reduced which causes further degradation of the soil. Clay content in sites 1, 2 and 4 exceeded 40%. This is attributed to illuviation and *in situ* weathering processes (Taimeh & Khresat, 1988; Irani, 1992). The clay content decreased from 64·5% at site 1 to 32·4% at site 6 (Table 2). As a result, the water-holding capacity and vegetative cover were less and soil structure became weaker rendering the soil was more susceptible to wind and water erosion at sites 5 and 6 (Taimeh, 1991).

### *Overgrazing problem*

The areas that receive 200–250 mm precipitation have sufficient vegetation to support grazing. These areas have been important grazing lands for the local population over the years (Juneidi & Abu-Zanat, 1993). The most noticeable effects of overgrazing at sites 5 and 6 included displacement of native vegetation by less palatable and often poisonous plants. The heavy burden placed by livestock on these fragile soils left the soil surface bare and compacted during much of the fallow period and thus highly

**Table 2.** *Relevant soil properties of the studied sites**

| Site | pH | EC (dS $m^{-1}$) | $CaCO_3$ (%) | Sand (%) | Silt (%) | Clay (%) | N (%) | OC (%) | P (mg $kg^{-1}$) | C/N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Jamha | 7·5 | 0·35 | 4·0 | 3·0 | 32·5 | 64·5 | 0·05 | 1·1 | 9·8 | 22 |
| 2 Husn | 8·2 | 0·45 | 17·7 | 6·5 | 42·0 | 51·5 | 0·07 | 0·6 | 5·5 | 9 |
| 3 Irbid | 7·9 | 0·41 | 10·0 | 5·9 | 57·6 | 36·5 | 0·06 | 1·0 | 6·7 | 17 |
| 4 Maru | 7·9 | 0·38 | 7·0 | 3·1 | 54·5 | 42·4 | 0·06 | 0·8 | 11·0 | 13 |
| 5 Ramtha | 8·0 | 0·51 | 12·2 | 5·5 | 61·0 | 33·5 | 0·06 | 0·7 | 5·2 | 12 |
| 6 Khanasri | 8·0 | 1·00 | 24·2 | 8·2 | 59·4 | 32·4 | 0·02 | 1·1 | 6·0 | 55 |

*Measurements are mean values of three replicates.

susceptible to wind and water erosion (Pearse, 1970). Erosion by wind and water is considered the major cause of land degradation in the area.

### *Tillage practices*

Four and six tillage operations during a fallow period of 16–18 months are very common in the study area (Jaradat, 1988). Use of heavy disks and moldboard ploughs as well as ploughing up and down the slopes intensified soil erosion. This was observed at sites 2, 3 and 4. The moldboard plough, which is still in use in certain parts of the country, does not leave any crop residues on the soil surface (Papendick, 1984). Other tillage implements, such as the chisel plough, may leave 75–90% of the crop residues on the soil surface, thus protecting the soil from wind and water erosion (Jaradat, 1988).

### *Paleoclimatic conditions and soil types*

The studied soils belong to Quaternary alluvium and colluvium parent materials formed on limestone and chert (Ministry of Agriculture, 1993) Soils in the study area belong to the orders Aridisols, Vertisols and Inceptisols (Table 3).

The country was subjected to several climatic changes during the Quaternary period (Rognon & Williams, 1977). The last episode of climatic changes, which prevails at the present time, is responsible for the development of unfavourable soil properties that accelerated degradation of many plant species. The climatic variations were as follows: pluvial period (40,000–20,000 years B.P.), dry interval (20,000–13,000 years B.P.), minor pluvial period (13,000–7000 years B.P.) and dry interval (7000 years B.P.–present).

Coupled with the effect of continuing drought incidents, plant cover removal was greatly accelerated in the study area (Taimeh, 1991). Data on the extent of soil erosion are not compiled. However, field observations clearly indicate the severity of soil erosion at sites 2, 3, 5 and 6 (sheet and gully erosion).

### *Urbanization*

Continuous growth of the population along with limited natural resources contributed to land degradation and desertification. With an average increase in the population of about 3% plus migration from neighbouring countries, the population increased from 3 million to 4·25 million in the last 10 years (Department of Statistics, 1994). This contributed to desertification through urbanization and loss of agricultural land. Expansion of urban and rural settlements was at the cost of cultivable land.

**Table 3.** *Soil orders, suborders and greatgroups of the studied sites (USDA system)*

| Site | Order | Suborder | Greatgroup |
|---|---|---|---|
| 1 Jamha | Vertisols | Xererts | Haploxererts |
| 2 Husn | Aridisols | Argids | Paleargids |
| 3 Irbid | Inceptisols | Ochrepts | Xerochrepts |
| 4 Maru | Vertisols | Xererts | Haploxererts |
| 5 Ramtha | Aridisols | Argids | Calciargids |
| 6 Khanasri | Aridisols | Cambids | Haplocambids |

## Conclusions

Desertification in north-western Jordan is taking place through loss of soil fertility and productivity, overgrazing and water and wind erosion. Continuous cropping without supplying nutrients through fertilization depletes nutrients from soils of the region. These soils do not contain much organic matter and their alkaline reactions reduce the availability of phosphorous and micronutrients and consequently lead to very low crop yields. Nitrogen and phosphorous are the most critical limiting nutrients in these soils. Loss of soil fertility and productivity are the main consequences of land degradation in the region.

Although soils in the xeric regime are non-saline, they may be easily salinized if not managed properly because of their high clay content and high evaporation rate.

Implementation of soil conservation and erosion control measures such as contour ploughing, terracing and stonewall construction on farmer's fields help in curbing accelerated erosion and in protecting potential agricultural lands. All these measures reduce runoff by trapping water and increase the infiltration rate and vegetative growth. These measures are aimed at reducing water and wind erosion and are considered as a possible solution to land degradation in north-western Jordan.

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