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Man-induced Erosion in Northern Jordan

The work described in this paper was undertaken when the author was a member of a soil conservation team working in the Northern Highlands of Jordan between 1965 and 1968. The team's work was focussed on the Wadi Ziqlab in the north and the Wadis Kuffrein and Shueib in the south and formed part of a larger project of watershed management sponsored by the United Nations (FIG. 1).

The Northern Highlands consist of a plateau edge overlooking the Jordan rift valley, which is being deeply dissected by six major westward flowing streams. The long profile of these wadis shows average falls of between 35 to 48 metres per kilometre, with the steepest gradient often being found in the lowest sections. The Highlands attain their maximum altitude in two massifs to the north and south of the Wadi Zerqa. Near Ajlun in the north a height of 1,247 metres is reached, while in the south, near Salt, the highest land is 1,113 metres above sea level. The western edge of the study region is delineated by the 200 metres below sea level contour along the foot of the fault escarpment. Given the dissected nature of the region, gentle slopes of less than 15 per cent are rare and confined to ridge crests and benches along the valley sides. To the east, on the plateau itself, gentle slopes predominate. Steep slopes of more than 40 per cent are found along the lower portions of all the valleys. Moderate slopes of between 15 per cent and 40 per cent occur most commonly in this dissected upland and make up over half of the total area.

The rocks on the Northern Highlands are composed mainly of terrestrial and marine sediments dating from Jurassic to Tertiary times. In general the older rocks are arenaceous and terrestrial in origin, while the younger ones are calcareous and marine. All these sediments have in places been folded and faulted as the result of tectonic activity associated with the formation of the rift valley. Following uplift in the Middle and Late Tertiary, sub-aerial conditions have prevailed in Northern Jordan and the only recent sediments are alluvial sands and gravels found along the floors of the larger valleys.

The basal deposits in the area are sediments of the Zerqa Group composed of a complex sequence of sandstones, marls and in the upper layers, limestones. They are overlain by the Kurnub Group, of which the most important strata are loosely consolidated sandstones of terrestrial origin up to 350 metres in thickness. The most important rocks belong to the Ajlun Group which are clearly distinguished from the Kurnub Group by the abrupt cessation of sand deposition at this horizon. Almost all the strata of the Ajlun Group are calcareous, formed under uniform sedimentary conditions in a neritic environment. In general the lower units tend to be marly limestones, while the highest beds are hard crystalline limestones of up to 200 metres in thickness. The highest formations belong to the Belqa Group. These are of marine origin deposited under shallow water conditions and consist of chalky formations with associated cherty limestone and phosphate beds. Many of the upper beds have been silicified throughout much of their thickness.

In terms of the pattern of geological outcrop the older strata of the Zerqa Group are found only along the main east to west gorge of the Wadi Zerqa and in a narrow belt southwards along the margin of the rift valley. The outcrop of the Kurnub Group forms a broad arc around the Zerqa Group outcrop and is likewise confined mainly to the Wadi Zerqa area. However, faulting and tectonic activity in the southern part of the Northern Highlands has resulted in exposures of the Kurnub Group being found in the deeper parts of the Wadis Shueib and Kuffrein.

By far the largest proportion of the outcrop, over 50 per cent of the total area, is made up of rocks of the Ajlun Group. They are best exposed in the Ajlun area. To the south in the Wadis Shueib and Kuffrein, the Ajlun series still dominates the outcrop, but here the Belqa and Kurnub Groups are also present. The Belqa Group is best exposed in the Ziqlab watershed, though limited exposures have escaped erosion in parts of the Wadis Shueib and Kuffrein owing to downfaulting of large rock masses.

The Northern Highlands receive the highest precipitation totals in Jordan. The main features of the climate are long, hot and dry summers and a relatively short and wet winter, when temperatures can fall below freezing point. The altitudinal range of the Northern Highlands, which is more than 1,200 metres, means that widely different temperature conditions prevail throughout the region. Climatological stations along

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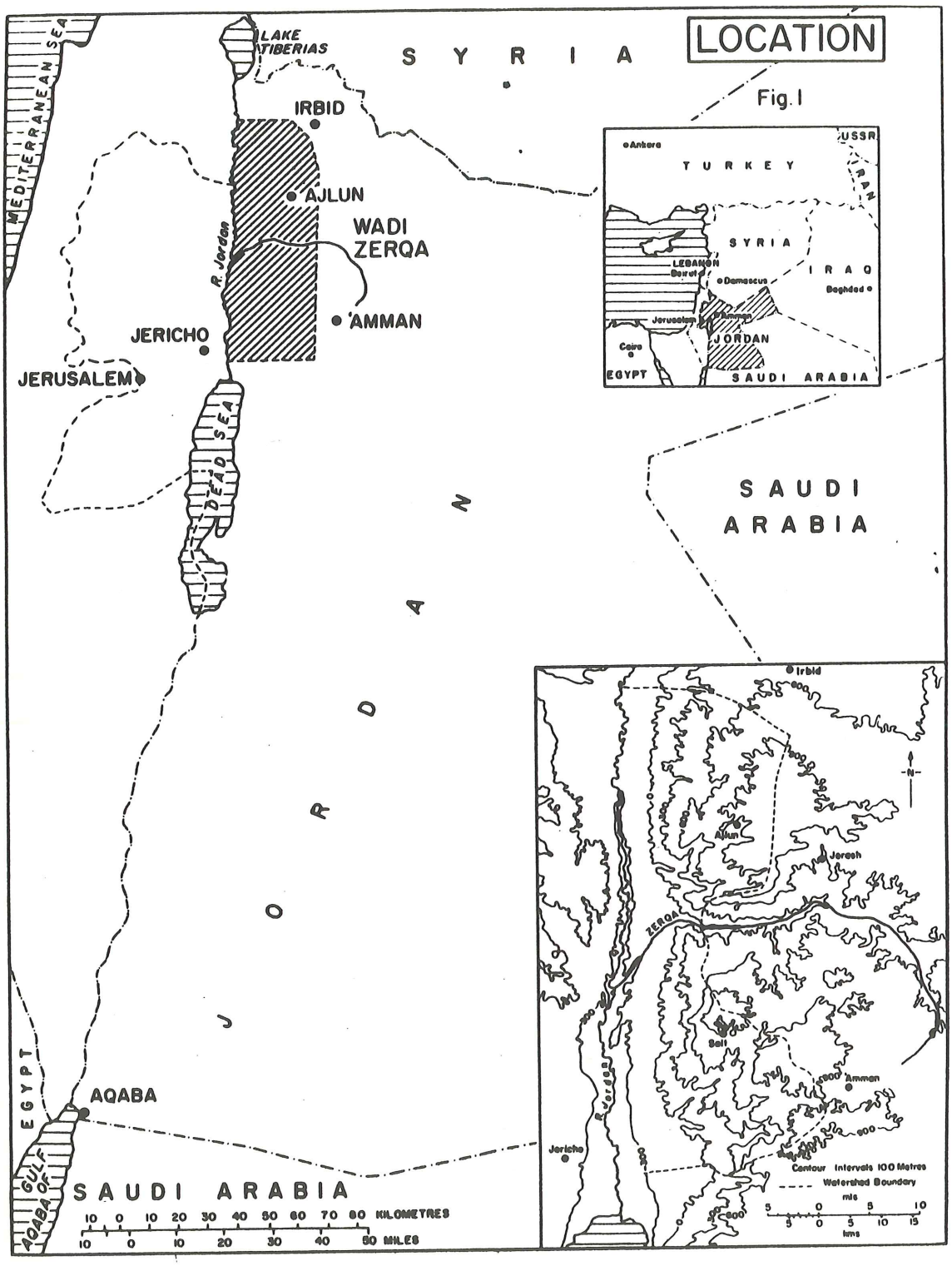

the Jordan valley indicate that the lower courses of the main wadis experience minimum monthly temperatures of 10° to 12° C in December and maximum monthly temperatures of 29° and 32° C in August. In contrast, the higher parts of the uplands record January minimum monthly temperatures between 3° and 6° C and August maxima between 22° and 25° C. In the rift valley lowlands frosts are rare, while on the plateau around Amman the days with frost vary between five and 15 each year.

Almost all of the uplands receive more than 300 mm. of

precipitation. The two major highland zones, centred around Ajlun in the north and Salt in the south record annual totals in excess of 600 mm., while to the east and west precipitation amounts decline rapidly to less than 200 mm. per annum. Annual variability of precipitation is high with many stations recording maximum values which are almost four times greater than the minimum values. Approximately 95 per cent of the precipitation falls in the winter period from November to March inclusive, and within this period the three months of December, January and February usually account for about 70 per cent of the total. The actual number of rain days is small with most stations recording between 30 and 50 days each year.

In terms of rainfall intensity over half the stations have recorded extreme values of more than a 100 mm. in 24 hours. However, average falls are much lower, with about two-thirds of all rain days recording less than 10 mm. of precipitation. Rain days with more than 25 mm. make up only 10 per cent of all observations. When one considers total rainfall one finds that the rain days with less than 10 mm. account for only 25 per cent of the total, despite the fact that they make up two-thirds of the observations. In contrast, rain days with more than 25 mm. provide one-third of the total rainfall in the northern area and almost 45 per cent of the total in the south. Bearing these data in mind it can be seen that severe soil erosion in the Northern Highlands is limited to a dozen or so rain days a year when precipitation intensities are high (FIG. 2).

On the whole the soils of the Northern Highlands are closely correlated with geological lithology, especially in the wetter areas. In the north the most widely distributed soils are Terra Rossa soils associated with outcrops of massive and crystalline rocks of the Ajlun Group. Profiles vary from thin and truncated cultivated sites to deep and mature profiles under *Quercus* woodlands. These Terra Rossa soils are of heavy texture with clay contents of between 50 and 70 per cent. Silt contents are variable, but often high, while the sand fraction is consistently low. Soil moisture storage capacity is high, providing adequate water for the growth of cereals during the summer months.

A brown limestone soil is developed on a variety of soft and marly limestones and occurs over a wide area, particularly around the Wadi Zerqa watershed. This soil is intermediate in character between the Terra Rossa soil developed on the hard crystalline limestones and the rendzinas on soft chalks. Clay and silt contents are lower than the Terra Rossas and free carbonate significantly higher, between 15 and 30 per cent. As the limestones become more marly the brown soils grade into

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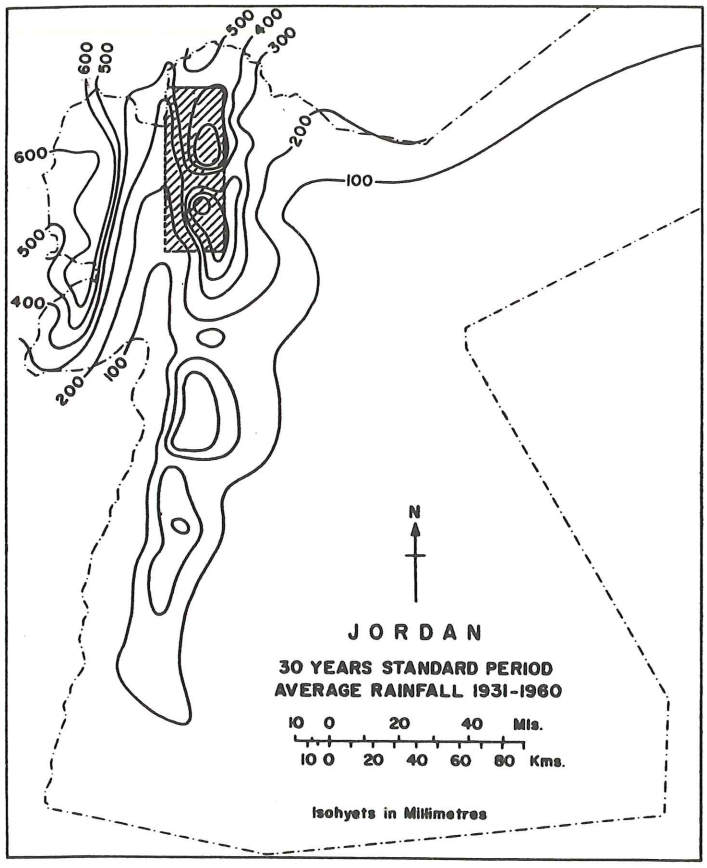
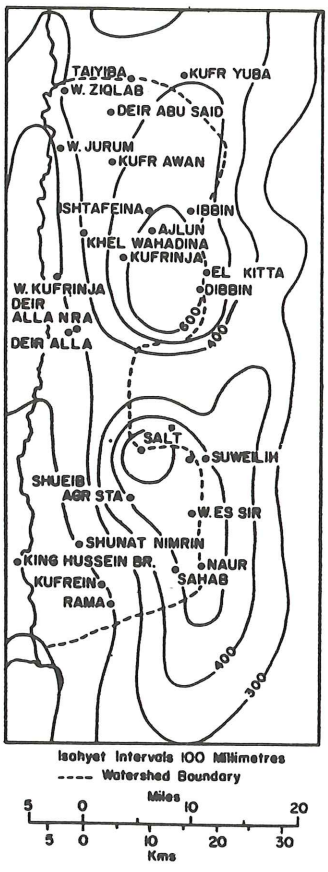




grey limestone soils. Rendzina soils are confined to outcrops of soft chalky limestones and marls. In terms of area of occurrence they are relatively unimportant, but often provide good arable land near village sites. Profiles often reach a metre in depth and are easily penetrated by roots. These are highly calcareous soils.

The siliceous and cherty facies of the Belqa Group provide the characteristic material of the Brown Cherty Soil Group. This occurs mainly in the eastern margin of the watersheds and often covers large areas. The characteristic features of these soils are their dull brown colours and high chert contents. Textures vary from clay loams to silty clays.

Soils developed on the Zerqa and Kurnub sandstones are the only significant ones derived from non-calcareous parent material. A wide variety of colours are found, though the dominant ones are red, reddish yellow or brown. Soil texture is light, ranging from sand to sandy loam. The most striking features of these soils are their friability, free draining nature and weak structural development.

On areas of moderate and steep slopes the identification of soil units is complicated by soil washing and colluviation. Profiles are often truncated and material is relatively fast moving downslope. Three major types of slope soils have been identified. Brown slope soils are the slope equivalent of Terra Rosa and brown limestone soils, while grey-white slope soils are associated with marls and poorly consolidated limestones. Yellow-brown slope soils are found on colluvial slopes and contain a high admixture of standstone. Given the steep slopes on which they occur all these soils have a high erosion potential.

The final group of soils are alluvial in nature and are found along the wadi floors and wadi terraces in the lower reaches of the main valleys. These are all of depositional origin and profiles are deep, though varied in composition dependent on local conditions. Although this description has concentrated on the identifiable soils within the Northern Highlands it has to be stated that bare rock outcrops make up a significant proportion of the total area.

A feature of the Northern Highlands is the extensive forest remnants composed predominately of evergreen oak (*Quercus coccifera*) with sporadic Aleppo Pine (*Pinus halepensis*) and deciduous oak (*Quercus aegilops*). The forest is concentrated in the wetter parts of the highlands with the largest remnants occurring near Ajlun in the north. Besides providing a forest cover the high precipitation has proved attractive for human settlement and over the years a large number of villages and small towns have grown up. Ajlun in the north and Salt in the south are the major regional centres. Cereals form the staple produce, but a wide variety of crops including vines, olives, melons and tobacco and vegetables are also grown. Pastoral activities on the uplands are important with sheep and goats the main animals.

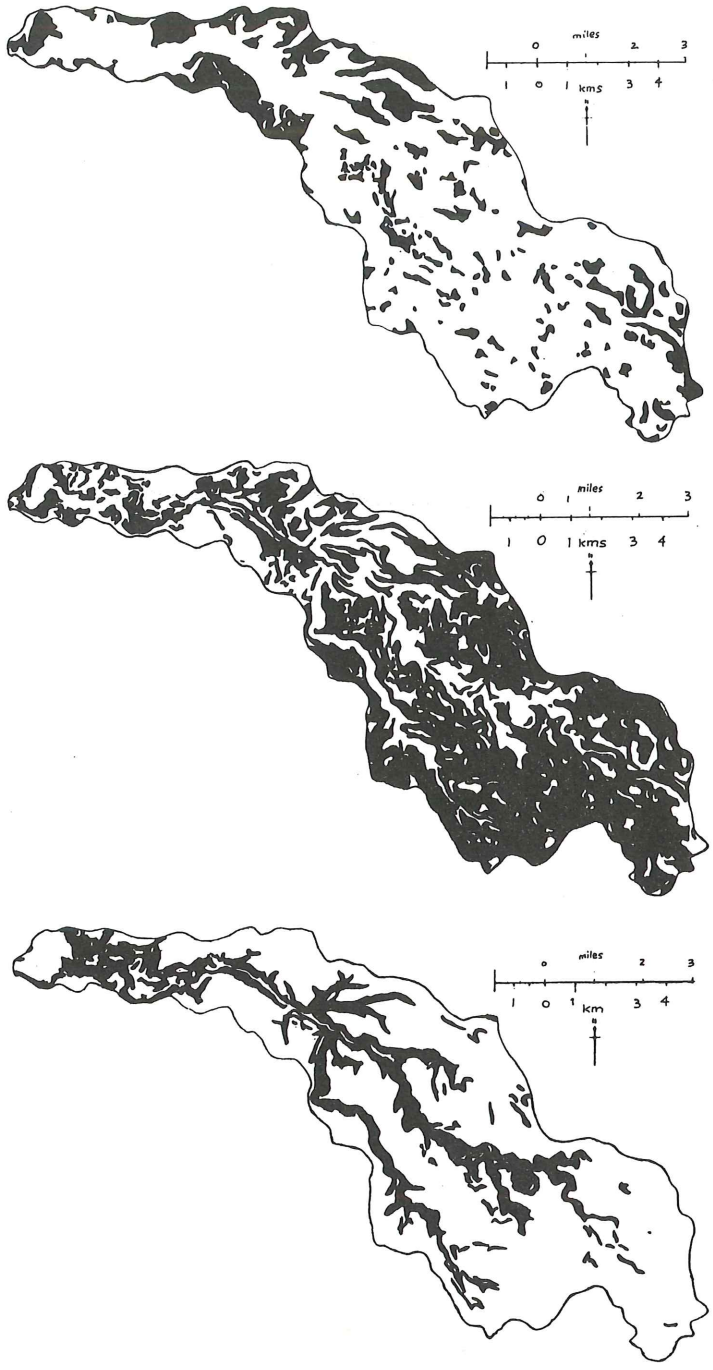
The long history of human settlement has accelerated the rates of soil erosion within Northern Jordan. However, it should be stressed that in the Northern Highlands erosion potential was already high because of the steep slopes and the nature of the soils. Truncation of the upper soil horizons is widespread and it is rare to see a stable, fully developed profile. As the natural profiles tend to become more indurated with depth, progressive erosion exposes the poorly structured sub-soil. These sub-soils have lower infiltration rates, which cause more overland flow and hence greater erosion.

One of the most significant soil properties as far as erosion is concerned is the lack of stability of the soil structural units under the combined influence of wetting by precipitation and the impact of raindrops. The addition of water to most of the soils of Northern Jordan breaks down the aggregates into their constituent particle sizes. These particles clog the macropores and form an impermeable surface crust, which in turn reduces surface infiltration and promotes increased runoff and water erosion.

The main impact of human activity has been the widespread removal of the vegetation cover, whether by deforestation, over-grazing or the monoculture of cereals. Of these deforestation is the most difficult to combat because forest rehabilitation is such a long-term process. Over the years woodlands have been cleared to provide additional agricultural land as well as timber and fuel supplies. Attempts to control deforestation have been introduced but have met with varying success.

Over-grazing of pastures and woodlands has meant that regeneration of many species has been prevented and in some cases, particularly around the villages, all the vegetation cover has been removed leaving large areas of bare soil and rock. Although it is possible in theory to control animal numbers it is difficult to do this in practice and it seems inevitable that overgrazing of certain areas will continue. Goats are a special problem as their very close grazing habits and their tendency to strip bark from trees prevents the regeneration of shrubs and trees. On the other hand the goat is an extremely efficient harvester of poor quality vegetation and hence very valuable in a semi-arid environment.

Four-fifths of the arable land is devoted to cereal cultivation, primarily wheat and barley. Cultivated fields are small, often very stoney, and mostly situated on slopes. This means that whatever method of cultivation is used some of the soil will move downslope under the influence of gravity and hence contribute to the erosion process. The most serious effect of cereal cultivation is that the ground surface is bare of vegetation during the winter months when precipitation totals are highest. The absence of vegetation, and hence, the lack of interception, allows raindrop splash to be particularly destructive. Once soil particles are dislodged there is little to hinder their downslope movement. Consequently sheet erosion of soils is particularly widespread whenever cultivation occurs. Indeed in the Wadi Ziqlab a series of gully plugs 80 cm. high were filled with sediments during three storm periods. It is interesting to note that owing primarily to the shallow nature of the soils gully erosion is not a serious problem in most of the upper parts of the watershed.



3. Slope gradients in the Wadi Ziqlab; (top) less than 15 per cent; (middle) 15–40 per cent; (bottom) over 40 per cent.

The severity of the erosion problem within the region can best be illustrated by slope maps and a land capability map (using US Department of Agriculture methods) constructed for the Wadi Ziqlab (FIGS 3 and 4). The slope map clearly shows how little land of low gradient exists within the watershed, while the land capability map integrates a variety of factors which hinder agricultural usage. Throughout the watershed Class II and Class IV land is widely cultivated, despite severe limitations. In some western parts of the wadi Class VI and even Class VIII land is brought under cultivation when no better land is available to a village. In one case ploughing was observed on a slope exceeding 40 per cent. Given this type of activity it is inevitable that soil erosion will continue to be a very serious problem.

Looking at the Northern Highlands as a whole it is obvious that the agricultural potential is limited, with the limitations resulting largely from progressive ecological deterioration. This deterioration is partly the result of man-made pressures

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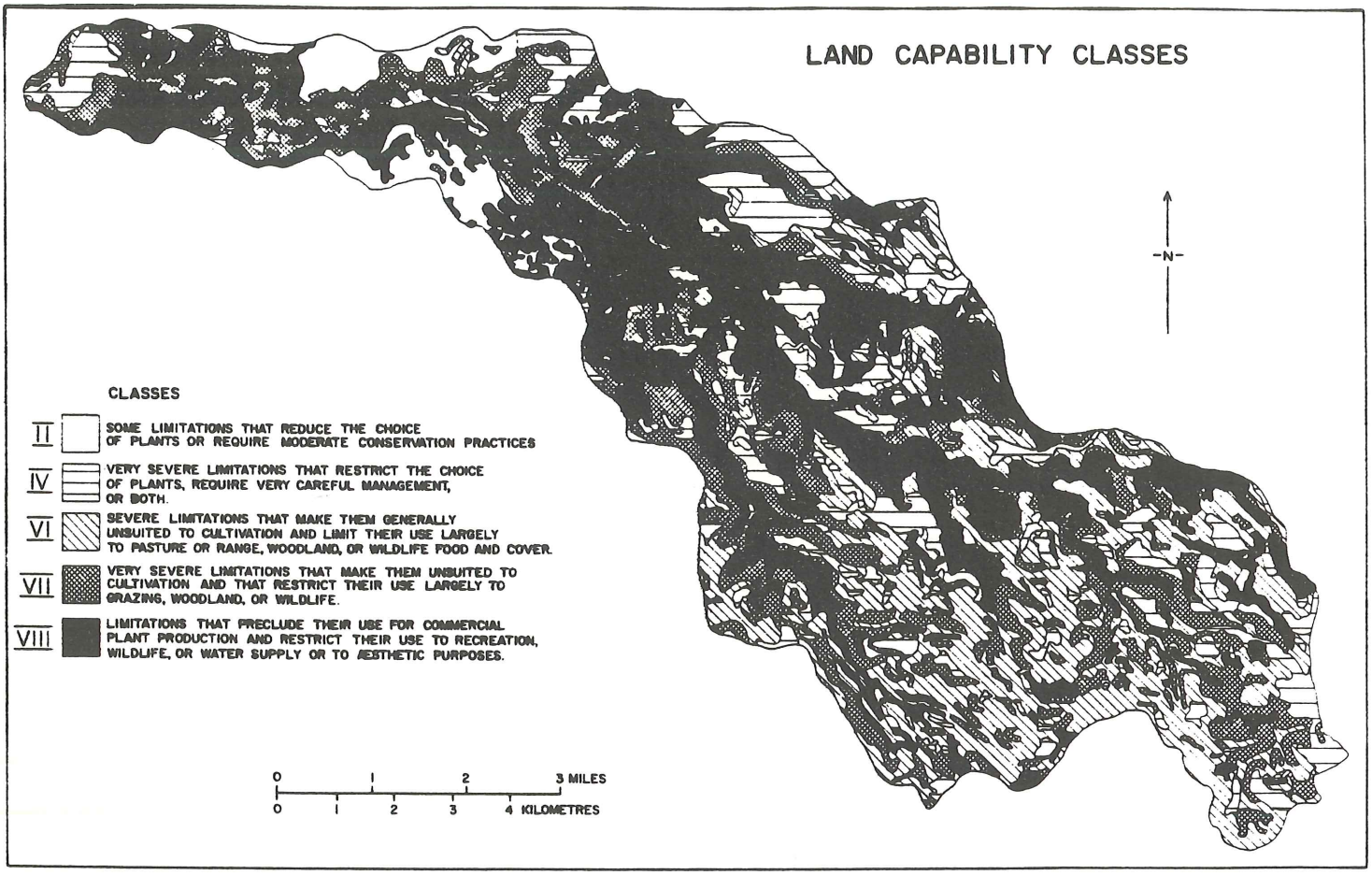

being exerted on what was already a fragile and delicately balanced environment with a very high erosion potential.

In conclusion this paper describes the environmental conditions which existed in the Northern Highlands of Jordan in the mid-1960s, prior to the initiation of a major watershed management programme. It stresses the cumulative effects which man's use of traditional agricultural practices has had on the rates of soil erosion and it emphasises the very severe environmental degradation which existed in many parts of the region at that time.

What became very obvious from the study was that any adequate remedial measures had to involve some positive re-orientation of landuse and land management practice as well as 'negative' or prohibitory conservation measures. The justification of such action was that if something was not done then further rapid deterioration of the environment would occur. At the same time it had to be recognised that many villages and towns existed within the Northern Highlands and that their inhabitants had to obtain a livelihood from the land. This meant that it was impossible to implement an ideal conservation strategy insofar as large areas of land currently being farmed would have to be withdrawn from cultivation. Therefore, any conservation programme had to focus on those areas where soil erosion was most severe and yet at the same time permit maximum agricultural productivity with minimum land degradation.