Chapter 6
Agriculture: Grazing Lands and Other Grasslands

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Abstract Compared to industrial activities or transportation, grassland management alters the surface to a modest extent. Under favourable topographic, soil and climatic conditions, with reasonably planned grazing, the growth and consumption of grasses are in balance. When any of these factors is significantly changed, the grass cover becomes interrupted, and this influences geomorphic processes. A well-known case is the sensitive environment of the Sahel, where delicate equilibrium was upset by large-scale growth of the animal stock – aggravated by natural climate change. The extension of grazing lands and the abandonment of the traditional ways of farming induced desertification. Significant damage by trapping and soil compaction is observed at the gathering places of animals. In the arid season, tracks leading to watering holes are hardened barren surfaces. In humid periods, however, these are wetlands where intensive trampling causes the incision of ravines along the tracks. Similar phenomena can also be observed, although sporadically, under temperate climates. However, the problems of grasslands in the temperate climatic belt are also of concern of agriculture, landscape protection and nature conservation, since the subsistence of the population here is not so dependant on the utilization of grasslands as in the Sahel. Human alterations on the grasslands of Hungary took place mainly through water management, various technologies introduced to cultivation and utilization of various intensities (grazing or mowing).

Keywords Grazing · Grasslands · Desertification · Grassland management

6.1 Introduction

Agriculture, in general, especially grassland management, results in less remarkable alterations as compared to industrial activities or transportation. Apart

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from the physical conditions, geomorphic evolution on grasslands depends on the methods and intensity of use. Under favourable topographic, soil and climatic conditions, with reasonably planned grazing, the growth and consumption of grasses are balanced. When conditions are partially or completely changed, the grass cover becomes interrupted, and this influences geomorphic processes.

This chapter intends to provide an introduction to the geomorphological problems of two grasslands under different climates through case studies. First, the causes of grass cover degradation and desertification taking place in the Sahel, i.e. in the northern marginal areas of the Sahara are discussed in detail, followed by the alterations observed on Hungary's pastures.

6.2 Anthropogenic Geomorphological Problems of the Sahel

6.2.1 Concept and Physical Geography of the Sahel

Sahel is an Arabic word meaning 'shore'. It is the name used for North Africa's sandy, dune steppe-like coastal zone, especially in Algeria and Tunisia. However, the term Sahel more often refers to the belt to the south of the Sahara, from Senegal to Sudan, along the boundary between the desert and the arid thorny savannas, between approximately 12°–15°N (Gábris 1996) (Fig. 6.1). The name Sahel was introduced to the scientific literature by Auguste Chevalier, a French botanist in the early 20th century to mark regions south of the Sahara (Élesztős et al. 1993). Due to the descending air in the Sahel, the annual amount of precipitation is low (125–250 mm); the period of rainfall lasts only for 6–12 weeks (Adams et al. 1996). There are no surface water-courses; fossil sand dunes are bound by the sparse, shrub and grass vegetation.

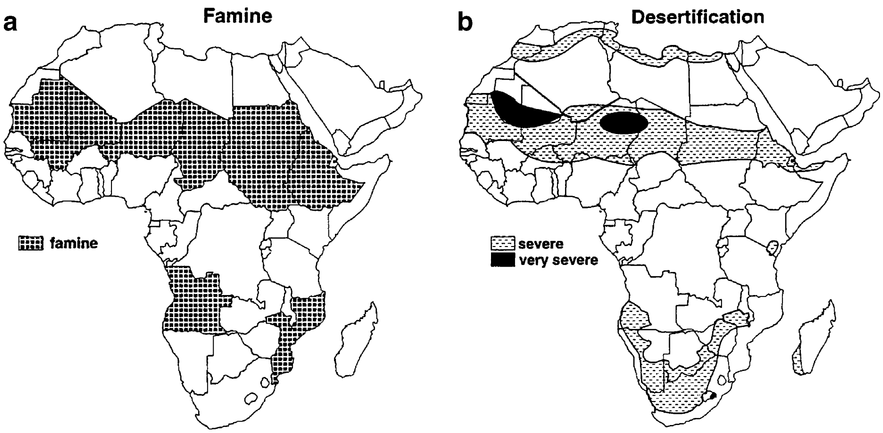

Fig. 6.1 Extension of the areas affected by drought and desertification in Africa (Thomas 1993)

The area of Sahel experienced millennia or centuries of alternating humid and hyperarid climate over the Pleistocene and Holocene. In the humid periods, the belt was characterized by humid savanna vegetation, while in the arid periods, the desert sand dunes extended far to the south (approximately to the 10°N latitude), leaving fossil sand dunes fixed by grasslands to the south of the present-day wind-blown sand areas with an annual rainfall of 1,000 mm today.

The Sahel vegetation is characterized by arid grasses, spiny shrubs and short thorny acacia trees. Soils are mostly loose sandy, while saline-clayey soils (formed on the alluvia of rivers and lakes) demand drainage. They are rather susceptible to wind and water erosion and are quickly desiccated by intensive evaporation.

In the semi-desert areas south of the Sahara, social impacts were long insignificant, and the area itself was in an ecological equilibrium. People only exploited natural resources without exhausting them. The native lifestyles and economy of peoples practising *transhumance husbandry* and subordinately (sorghum and millet) *farming* maximally adapted to the low productivity of grazing lands, and the subsistence of a limited human and animal population was ensured. The mobility of transhumance husbandry proved to be fundamental for surviving drought periods.

6.2.2 The Problem of the Sahel – Factors of Desertification

The sensitive environmental balance of the Sahel was repeatedly upset by the climate change in the past decades combined with a population boom. The resulting expansion of animal stocks together with grazing lands and the abandonment of the traditional way of farming induced desertification. As a consequence of drought years occurring since the mid-1960s, starvation and the degradation of animal stocks ensued. The dust and sand carried here by the stormy northern desert trade winds disparting the scorched surface, called the *Sahel wind,* contribute to the southward expansion of the Sahara. According to recent research, both physical and social factors contribute to desertification.

6.2.2.1 Physical Factors

First, regional climatic oscillations, reflected in altered precipitation patterns, should be mentioned. The *annual amount of precipitation* has decreased by more than 20% as compared to a more humid period between 1920 and 1939. In the more arid spell between 1965 and 1984, annual mean precipitation dropped from 200 mm to below 160 mm. This basically means the displacement of certain isohyets running roughly parallel to geographical latitudes to a southern direction to a distance of ca 50 km (Adams et al. 1996). The decrease in the amount of precipitation results in *lesser days with rainfall*, while, at the same time, the *intensity of rainfall increases*. Rainsplash erosion during major and violent downpours attacks the land surface and removes large amounts of soil. There is an increase in the *variability of the amount of precipitation* between years and rainfall becomes unpredictable. The lack of rainfall is the most common in the middle and in the end of the growing season (in August), which are the period of sorghum and millet ripening, and causes a drop in average yields.

6.2.2.2 Human Impact – Anthropogenic Geomorphologic Changes

In most of the Sahel, the low amount of precipitation allows crop cultivation only if regular irrigation is provided (Penning de Vries and Djeteyé 1982). Thus, the quantity and quality of yield highly depends on the various irrigation techniques. Recently, population increasingly concentrated next to the wells drilled and along irrigation channels. Rapid population growth is the root of environmental problems. Figure 6.2 indicates social causes in detail.

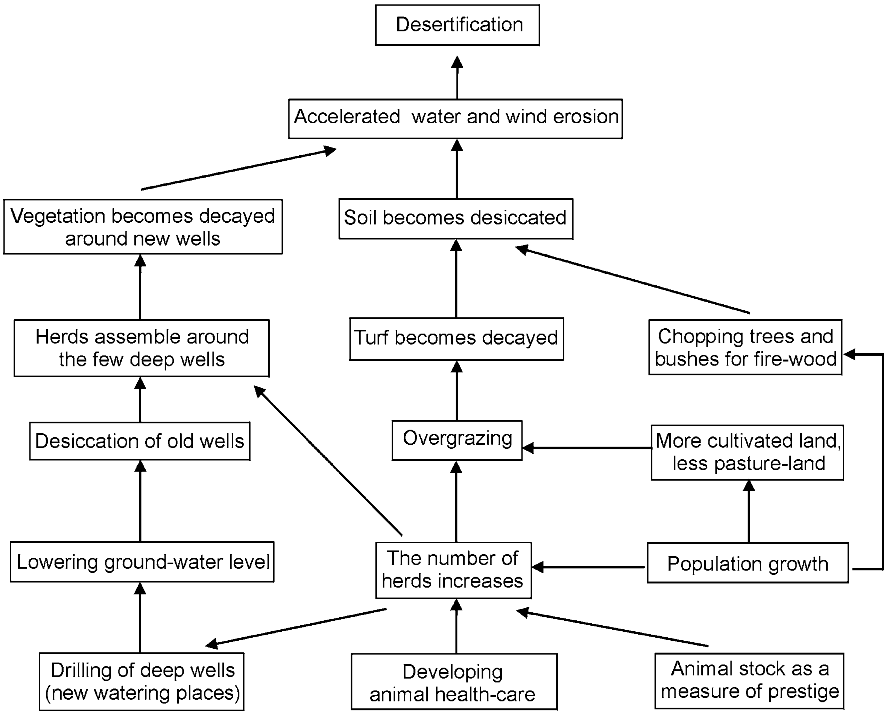

Fig. 6.2 Human factors in the desertification of the Sahel (Probáld 1996)

The fundamental problem, therefore, is not grazing but *overgrazing*, i.e. the overpopulation of animal stocks in a given area. As a result of the growth in the animal stocks induced by the population expansion, in many cases, instead of 0.5 animal unit (1 animal unit is an equivalent to 1 calf older than 2 years, or 2 so-called animals of last year younger than 2 years, or 5 sheep or goats), 5–10 animal units or even 20–25 animal units are grazed in the Sahel, accelerating the decay of grazing lands and leading to desertification (Binns 1995). Significant damage by *trapping and soil compaction* is observed at the watering holes, where animals gather. Overgrazing is detectable *in the soil profile*, in the degradation of the humus horizon. *Tracks* leading to watering holes are the sites where erosion starts. Such tracks are, in the arid season, hardened barren surfaces, while in the humid period, they are wetlands impossible to use where intensive trampling causes the incision of *ravines* along the tracks. Later a similar new track, parallel to the former one, emerges.

In the Sahel, as many as 6,000 heads of cattle as well as 50,000 sheep and goats can gather at a watering hole daily (Nir 1974). As a practice used in many countries, cattle is washed once a week in a communal tank in order to prevent diseases spread by acari. These giant tanks are found all over the region, thus the cumulative impacts of driving cattle across the land result in ravine formation and wind erosion of remarkable scale. There is a close correlation between the various levels of grazing intensity on slopes and the level of soil erosion. Overgrazing can often lead to remarkable sediment accumulation along the lower reaches of rivers.

As a result of the factors mentioned above, in the past 30 years, the total area of deserts has increased from 1.4 billion hectares to 1.6 billion hectares, an annual growth of 5–6 million hectares. Desertification, therefore, does not simply spring from the decay of the natural ecosystem but from the upset dynamic equilibrium between humankind and nature, the collapse of a traditionally well-functioning production system.

6.2.3 Solution Opportunities

In 1977, an urgent action was pronounced at the UN Conference on Desertification (UNCOD) to prevent desertification, a major problem since the tragic aridification of the Sahel belt since the 1960s. International research into desertification today studies erosion, warming (climate change – El Niño phenomena) and local circumstances blamed for such processes. Basically two kinds of solution are thought to be appropriate: governmental administrative interventions or returning to traditional farming ('indigenous strategy').

The first did not prove to be effective enough. Many of the projects related to national and international organizations failed because of resistance from the population (as, for instance, protecting the remaining arboreous vegetation by barbed wire fences) or even worsened the present situation (drilling of deep wells → greater number of animals → overgrazing). Afforestation and the widespread use of species with short vegetation period however proved to be advantageous.

As 'modern' methods did not bring a breakthrough in solving the region's problems, many researchers see the revival of traditional and conventional cultivation methods as the only way out. All agree, however, that securing social stability in the region through ending war conflicts, the solution of the Sahel's urgent problems would be substantially promoted.

6.3 Anthropogenic Geomorphological Problems of Hungary's Grasslands

6.3.1 The Distribution and Occurrence of Grasslands in Hungary

Grasslands in Hungary amount to 1,299,739 ha (12,998 km^2), of which grazing lands have a share of 871,990 ha (8,720 km^2) and meadows 427,749 ha (4,278 km^2). It means that 14% of Hungary's area is grassland (Vinczeffy 1993).

Over the past centuries, with the expansion of agriculture, the extension of grasslands has significantly dropped. By bringing high-quality grassland soils under cultivation, grasslands became almost exclusively restricted to poor-quality soils unsuitable for farming. These soils with poor water budget, inadequate nutrients supply and shallow topsoil can usually be found in the drought-stricken Great Hungarian Plain. As the average annual amount of precipitation is 574 mm and the mean annual temperature is 10.5°C in Hungary, agro-ecological surveys claim that Hungarian grasslands suffer from a rainwater deficit of 156 mm per year. It is even more unfavourable in the plains where the yearly deficit is 214 mm on average. Mountain grasslands are in a more advantageous situation as the deficit is only 51 mm. Most grasslands are found on saline soils (alluvial solonetzes and solonchaks), while others on brown forest, alluvial and bog soils (Table 6.1).

6.3.2 Grassland Classification

Permanent grasslands are classified by their utilization as (1) *pastures,* (2) *hay-fields* and (3) *meadows*. Pastures are grasslands where the fresh yields are used by grazing animals during the vegetation period. On hay-fields, grass is exclusively harvested by mowing. Meadows are mostly mown and subordinately grazed. Pastures, hay-fields and meadows are further classified by various criteria (origin, character, animal species and exposure). Based on their *origin*, pastures can be natural and artificial. Natural pasture or grasslands include original grasslands formed under natural circumstances and have avoided disruption by major human intervention. Artificial pastures, on the other hand, bear the signs of human interventions (sowing, fertilization, irrigation) along with some features of a natural grassland.

Based on their *type*, permanent and temporary grazing lands are distinguished. Permanent pastures are exclusively used for grazing. Temporary pastures are areas grazed for periods of variable length either as a necessity or for the purpose of a better use. Meadows, fallows, stubble fields, plantations and forests are examples.

Pastures can also be classified by the *animal species* which they optimally feed. From such an aspect, cattle, horse, sheep, goat and goose pastures are distinguished. For *cattle pastures*, lowlands well covered by good-quality fibrous long grasses are the most suitable. Cattle spare most of the grass cover as they pick grass by their tongue, leaving adequately high, ca 2 cm stumps. Total mastication only occurs when the pasture is overgrazed. *Horse pastures* are areas with harder soils and

Table 6.1 Main features of the soils of Hungary's grasslands (Vinczeffy 1993)

Main types	Area 1,000 ha	Area %	Slope gradient (%)	Area 1,000 ha	Area %	Humus content	Area 1,000 ha	Area %
Skeletal soils	84	7	0–5	650	50	0	40	3
Brown forest soils	238	18	5–15	290	23	0–1	125	10
Chernozem	130	10	15–25	280	22	1–5	694	54
Saline soils	392	31	Above 25	63	5	5–10	272	21
Meadow soils	217	17	Total	1,283	100	Above 10	152	12
Bog soils	161	12	pH			Total	1,283	100
Other soils	61	5	3.5–5.5	156	12	Soil water management according to water intake and storage		
Total	1,283	100	5.5–6.5	640	50			
Soil depth			6.5–7.5	276	21	Very poor	490	38
			7.5–8.5	87	7	Poor	310	24
2–20 cm	503	39	Above 8.5	9	1	Moderate	186	15
20–50 cm	374	29	Mixed	115	9	Good	177	14
>50 cm	406	32	Total	1,283	100	Excellent	120	9
Total	1,283	100				Total	1,283	100

harder grass. Horses snap at greater depths compared to cattle picking the grass with their lips. They often cut grassland vegetation and also trample heavier and, as a consequence, exploit pastures to a greater degree. *Sheep* and *goats* exploit the short-growing, less valuable turf of arid areas. Sheep snap at greater depths, often getting hold even of stern nodes of grasses and pulling up the whole plant from the soil while grazing. Goats tend to consume all vegetable parts (including the shoot and seedlings of low bushes) leaving barren lands behind. Sheep and goat pastures in Hungary are mostly arid areas of low fertility. Therefore, valuable plant stocks can only be maintained on them by regular management (including fertilization). When *pigs* are unable to find an adequate amount of forage, they dig up the whole pasture. Adequate care should be taken, otherwise the whole grassland can be easily destroyed. Among the domestic fowls, *geese* are the greatest hazard to pastures. Therefore, grazing areas of the poorest quality should be designated for them. Geese consume all green vegetable parts and pollute the air by their feathers and caustic excrements. Stocks of several hundreds leave barren surfaces behind on which only some aggressive weed species are able to grow.

Based on *exposure*, mountain, hill, lowland, riparian and wetland pastures are distinguished. Mountain pastures are situated at an elevation of 800–1000 m, having abundant and substantial vegetation. Hill and lowland pastures are often eroded, mostly in arid locations and grasses have a moderate growth rate on them. Riparian pastures are found along rivers and covered by grasses. They are among the most valuable pastures, particularly suitable for cattle – if not waterlogged. Wetland pastures in waterlogged areas usually have a harsh vegetation mainly consisting of sedges. They are mainly utilized by pigs and, to a limited degree, by cattle.

6.3.3 Geomorphological Consequences of Grassland Management

In order to achieve a better exploitation of pastures and to maximize grass yields, humans have been intervening in the natural development of grasslands for centuries (Baksay 1996). In Hungary, especially in the Great Plain, nomadic herding was common until the late 13th century. In the 14th century, permanent settlement and the first regulations on grazing marked the advent of grassland management. Grassland management in the modern sense, however, did not emerge until the late 19th century and began to develop dynamically after World War II.

Human interventions affecting grasslands can be divided into four groups: (1) water regulation of grasslands, (2) various cultivation techniques, (3) fertilization and (4) utilization (grazing, mowing). The latter two factors have already been discussed and, therefore, the geomorphologic consequences of water regulation of grasslands and cultivation techniques are reviewed here.

6.3.3.1 Water Regulation of Grasslands

Abundant grass yields require water regulation. It has a twofold purpose: on the one hand, harmful excess water has to be removed; whereas on the other, an adequate amount of water must be supplied for the grasses at the right date. The most common and, geomorphologically, the most spectacular way of fighting waterlogging is *open-ditched land drainage*. Excess water is essentially drained by a network of lateral and collecting ditches interconnected from waterlogged areas (Plate 6.1). Lateral ditches join the wider and deeper trunk ditch which allows constant water flow. The density of the ditch network depends on the soil cohesion and the degree of waterlogging. A disadvantage is that the ditches occupy extensive areas, impede transportation and large-scale cultivation, the annual costs of cleaning is not negligible either. However, it has the advantage of draining large amounts of water within a short period of time at a relatively low cost.

Plate 6.1 Drainage ditch on a saline pasture in the Hortobágy (Tóth 2003)

On cohesive soils with appropriate stability, *uncased mole draining* made by drainage-plough is also applied. Underground hollows can easily cave in on sandy soils and bog soils, thus the technique cannot be applied there. Compared to the use of plastic drain pipes, they are cheaper, however with a shorter duration.

By draining excess water, significant changes can take place in the grass associations. By dropping groundwater table, acidic sedges and other plants (Cyperaceae, Yellow Iris – *Iris pseudacorus*, Ranunculaceae, Water Mint – *Mentha aquatica*, Pennyroyal – *Mentha pulegium*) decrease, with them having been replaced by sweet grasses (Creeping Bent – *Agrostis stolonifera*, Meadow Foxtail – *Alopecurus pratensis*, Reed Canary-grass – *Phalaris arundinacea*).

Based on experiments carried out in Hungary, it can be claimed that the undisturbed evolution of turf mixtures requires an annual amount of precipitation of approximately 700 mm under the climate of the country. On the contrary, however, grasslands in lowlands only receive 548 mm rainwater on the average. Consequently, water supply must also be provided. Four types of *irrigation* are known: (1) *flooding,* (2) *border dyke irrigation,* (3) *surface sprinkler irrigation* and (4) *'nesting' and furrowing*. Of the four methods mentioned above, 'nesting' and furrowing cause spectacular geomorphologic alterations on pastures. 'Nesting' and furrowing cannot actually be regarded as irrigation as they only focus on the retention of winter snow-melt and spring rainwater. During nesting, depending on the gradient of the field, ridges 20–30 cm in height should be formed by commonly applied ploughs with a distance of 60–100 m along the contour lines, then perpendicular to them. The network of rectangular nests impedes the immediate runoff of snow-melt and early-spring rainwater by retaining the adequate amount of water. Therefore, there is no need for irrigation proper.

The deepening of drainage and irrigation ditches, especially in saline areas can trigger significant erosion processes. On channel banks with more disturbed soil, landforms similar to natural salt berms; (however, developing more quickly and being more remarkable) are observed. *Salt berm erosion* is common here. Above the lower, older and steeper berm edge, the top berm is intensively eroded by rilling and sheet wash, and gradually decays into a barren and glaring white surface, where some specimens of halophilous specialist plant species appear. The intensive lowering of the lower berm top brings about an upper, younger and more gently sloped berm edge (Plate 6.2). Incising into the berm surface, the saltwater rills create gaps across the berm edge. In the foreground of this hollow, the rills usually accumulate miniature alluvial fans. The intensive decay of berm tops often produces surfaces similar to badlands on which percolating water often springs along berm forefronts (Plates 6.2 and 6.3). This process requires a relatively steep gradient, provided along the banks of artificial drainage and irrigation ditches (2.5 m drop at 10 m distance). In addition, intensive trampling by animals (Plate 6.3) and heavy showers also play

Plate 6.2 Formation of a two-stepped salt berm on the edge of a drainage channel in the Hortobágy (Tóth 2003)

Plate 6.3 Channel bank intensively formed by rill erosion and sheet wash in the Hortobágy (Tóth 2003)

a major part in berm formation. Runoff from showers can easily dissect disturbed, loose ditch banks. Under favourable conditions for erosion, annual berm regression can reach 10–15 cm and a surface lowering of 2–3 cm is observed, resulting in a gradual decrease of pasture area year by year (Tóth 2003).

6.3.3.2 Cultivation Techniques of Grasslands

Stony pastures frequently occur in mountain areas and river valleys of Hungary. Unfortunately, more and more pastures accommodate immense amounts of rubble, bricks, glass, tiles, etc. Stones are harmful on pasture as they cause injuries to animals, also dehydrating the soil when intensively warmed and spreading weeds. Therefore, the *collecting of stones* on the surface and at low depths is an important anthropogenic intervention on pastures. The stones collected are piled around watering holes and wells, and used for the construction of dams to control gullies, marking borders, road construction and other purposes.

On abandoned grasslands densely overgrown by bushes, a significant amount of area is occupied by shrubs instead of grasses. *Shrubs* have to be *cut* to improve conditions.

Overgrazing and the *damage* caused by *power machines* (wheel tracks) usually result in stripping of the closed grass cover, eventually the decay of soil structure (Plates 6.4 and 6.5). When the mass of grass cover amounts to 180 g/m^2 in dry mass, it provides excellent protection against erosion (Vinczeffy 1993). A natural consequence of the stripped surface and neglected soil scars, which mainly occur in mountainous and hill areas, the grass cover is interrupted and removed by

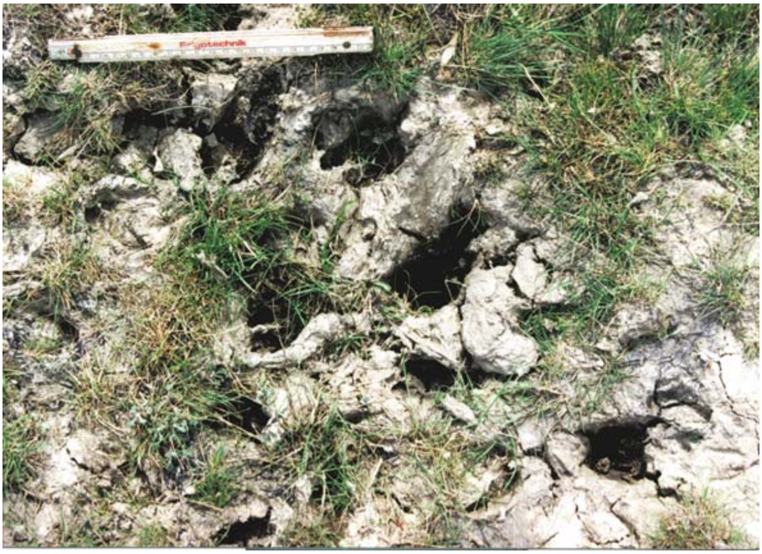

Plate 6.4 Grass cover disrupted by intensive grazing (of sheep) in the Hortobágy (Tóth 2003)

Plate 6.5 Saline grassland disrupted by heavy trucks in the Hortobágy (Tóth 2003)

incising gullies after heavy showers. The embryonic gully is broadened and deepened by runoff water. The gully banks cave in and extensive slumping takes place. The soil decayed will be transported by runoff water, resulting in further undercutting. Consequently, widening and deepening *gullies, ravines and gorges* are formed. Further development of steep gullies can be hindered by reducing slope along some bank sections, bringing them to trough shape, constructing dams of stones, stakes and twigs and planting *Pseudoacacia* trees and grasses.

When sand grasslands are overgrazed, not only erosion but also *deflation* becomes more intensive. Deflation can also be controlled by grassing.

In unmanaged grasslands on good soils, *mole-hills* are common. With time they are overgrown by grasses and colonized by ants. Thus, from a small mole-hill an ant-hill even half a metre high can develop in the course of time. When 15–20% of the grazing land in question is occupied by mole-hills and ant-hills, they are commonly levelled by a hoe or cleared away by shredders and planishers.

Tussocks also contribute to the unevenness of grazing lands. They partly develop by the growth of the roots of *Carex* species (e.g. Tussock sedge – *Carex stricta*); on the other hand, clumps of various sizes can be torn out by the trampling animals grazing on soggy soils. During intensive grassland management such small rises are pressed in the soil by plain radial roll as well as grass-comb.

6.4 Summary

Until transhumance husbandry along the desert margins or nomadic grazing under temperate climate was the only way of utilizing grasslands, equilibrium conditions were maintained between nature and human society. Especially, the changes in social conditions (population growth, the increase of animal stock, intensive grassland management, overgrazing) can result in the imbalance of grass ecosystems. This is well indicated by the example of the Sahel, an environmentally sensitive area. However, similar phenomena can also be observed, even if sporadically, under temperate climate. Solving the urgent problems of the Sahel, survival and improved quality of life can be ensured for millions of people. Although the subsistence of the population in the temperate climatic belt is not so dependent on the utilization of grasslands as in the Sahel, the problems of grasslands are also of concern to agriculture, landscape protection and nature conservation. Water management, various technologies introduced to cultivation and utilization of various intensities (grazing or mowing) have substantially altered the conditions of the grasslands of Hungary.

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