

Mapping the Degradation of Solonetzic Grassland

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Introduction

Degradation is a significant factor in the evolution of the solonetzic grasslands of Hungary and affects the landscape, the surface soil properties and also the living conditions of the fauna (VARGA, 1984; VARGA et al., 1982).

The objective of the work reported here was to study the applicability of aerial photography in the description of the status of vegetation and soil degradation in Hortobágy, Hungary.

Natural Conditions of the Study Area

Location and characteristic features of the study area

The Hortobágy National Park, which is devoted to the protection of the largest area of alkali grasslands in Central Europe, the preservation of the nesting and resting places of more than 200 bird species, the conservation of traditional animal husbandry, etc., is located between 47°45' and 47°25' N and 20°55' and 21°20' E.

The area is very flat; the mean altitude is 89 m above sea level, with most of the area lying between 88 and 92 m. The tumuli, or artificial burial mounds of earth are the highest spots, with a maximum height of 105 m.

The mean January temperature is -4.5 °C and July temperature is 21.5 °C. The mean yearly precipitation is 540 mm. During the vegetative period the climate is semiarid-semihumid (RÓNAI, 1975; TÓTH et al., 1991).

Soil conditions

As part of the Great Hungarian Plain, the formation of the Hortobágy region was dominated by the effect of rivers (MIKE, 1991). The flood control of the

River Tisza that took place in the last century and the drainage of the area drastically changed the conditions, since the territory dried out and the formerly frequently inundated areas now appear as salt-affected soils. The highest spots that were never covered by floods are made up of chernozem soils and the lower places are occupied by hydromorphic "meadow soils". As the so-called "szik" (alkali) soils are very characteristic of the Hortobágy region, there are numerous theories to explain the formation of these soils ('SIGMOND, 1923; SZABOLCS, 1988, 1989).

Some theories are intended to be general, or even universal for the formation of salt-affected soils, others are more local in their nature. The most important questions related to the formation of these alkali soils were the following:

- where do the salinizing-alkalizing salts come from;
- are the alkali soils the result of soil formation, or were there geologic processes involved, such as sedimentation;
- is leaching an important process in the formation of solonetz soils;
- what is the origin of the soda content of the soils?

Without going into the details of theories that still have their followers, we will follow the logic of DARAB (1967), who summarized the probable elements of some theories in a polemic. She writes that among the sources of salts the following should be noted: the feldspars of loess deposits, as minerals giving salts upon weathering; the groundwater that, within the Hungarian Plain, contains salts which were transported there from the mountains surrounding the Carpathian Basin, and in which salts from very deep layers can rise. The occurrence of salt affected soils is related to the position of the underground groundwater basins and to a high salt concentration in the groundwater. For the formation of the characteristic structure of solonetz soils she writes that both the capillary rise of groundwater and the seepage of precipitation is necessary. During the period of yearly salt accumulation the depth of maximum salt concentration is found at the upper limit of the capillary fringe and during the period of yearly leaching this depth is found at the wetting depth.

Vegetation

Due to the relatively simple chemical conditions of the soils and the extreme conditions of plant growth the natural vegetation on the solonetz soil reflects the soil conditions exceptionally well. So well, that on the basis of the original vegetation it is not only possible to estimate the fertility of the plots or prescribe management/improvement practices, but also to recognize the soil type, so a knowledge of plant associations is a help in soil mapping (BRAUN-BLANQUET, 1964; MAGYAR, 1928; WAISEL, 1972). On solonetz soils category systems already exist (BODROGKÖZY, 1965; MAGYAR, 1928; 'SIGMOND, 1923) for matching plant associations with soil types, so the use of these systems indicates the ranges of the most important properties of salinity, alkalinity or sodi-

city. Recently several efforts have been made to describe the spatial dependence of the soil properties and the correlation of vegetation on a field scale (RAJKAI et al., 1988; OERTLI & RAJKAI, 1988; TÓTH et al., 1991a).

The indication of soil properties by the vegetation in the solonetzic grassland is multifold, operating both at the species level and at the association level. The individual species are capable of indicating specific conditions of degradation (Table 1) and the plant associations represent different stages on

Table 1
Indication of certain factors of degradation by selected species of the
solonetzic grassland (after MAGYAR, 1928)

Species	Erosion	Culti- vation	Tram- pling	Weed
<i>Agropyron repens</i>	+	+		
<i>Atriplex litoralis</i>	+	+		
<i>Bromus hordeaceus</i>	+			+
<i>Gypsophila muralis</i>	+			
<i>Hordeum hystrix</i>	+	+	+	+
<i>Lepidium rudemale</i>	+	+		+
<i>Lolium perenne</i>		+	+	
<i>Matricaria chamomilla</i>	+	+		+
<i>Pholiurus pannonicus</i>	+	+		
<i>Polygonum aviculare</i>	+			+

the succession of the solonetzic grassland (BODROGKÖZY, 1964; BRAUN-BLANQUET, 1964; VARGA, 1984; VARGA et al., 1982) that may correspond to different soil degradation status. Table 2 shows the most important plant associations of solonetzic grasslands and Fig. 1 illustrates the most probable ways in which they developed.

Degradation

In this work degradation was defined as the lowering of the status of the soil and vegetation. The present occurrence of salt affected soils in the Hortobágy was much affected by human activity (MAGYAR, 1928), such as river regulation and drainage. At present soil degradation includes the water erosion of the A horizon of the solonetztes either by bank erosion or by sheet erosion. The compaction and tear-off of the soil surface caused by trampling should also be distinguished. The degradation of the vegetation includes the thinning of the vegetation cover, marked by a reduction in the total plant coverage, the disappearance of characteristic species and the appearance of weed species.

Table 2
Ecological conditions of the most important plant associations of the Hortobágy

	<i>Cynodonti-Poëtum angustifoliae</i>	<i>Archilleo-Festucetum Pseudovinae</i>	<i>Artemisio-Festucetum Pseudovinae</i>	<i>Camphorosmetum annua</i>
1. Biotope	rangeland	rangeland	rangeland	semi-vegetated or bare surface
2. pH of rootzone*	6.5 (6)**	6.1 (51)	6.8 (119)	6.9 (5)
3. EC of rootzone, mS/cm	0.10	0.07	0.14	0.19
4. Classification of soil (after 'Sigmund, 1923)	Class I, dry	Class II, dry	Class III, dry	Class IV, dry
5. Current Hungarian Soil Classification	(meadow) chernozem with saline subsoil	deep meadow solonetz	shallow meadow solonetz	crusty meadow solonetz
6. USDA Soil Class.	Vermustoll	Natrustalf	Natrustalf	Natrustoll
7. Soil degradation	none	slight erosion	slight bank erosion	fast, heavy erosion
8. Sensitivity	slight	slight	medium	none

	<i>Puccinellietum limosae</i>	<i>Bolboschoenetum maritimi</i>	<i>Eleochari-Alopecu- retum geniculati</i>	<i>Agrosti-Beckman- nietum eruciformis</i>	<i>Agrosti-Alopecu- retum pratensis</i>
1. shallow puddle		marshland	deep puddle	marshy meadow	meadow
2. 7.7 (15)		7.4 (12)	6.8 (3)	6.4 (5)	6.6 (36)
3. 0.41		0.31	0.38	0.08	0.11
4. Class IV, wet		Class IV, wet	Class III, wet	Class II, wet	Class I, wet
5. crusty meadow solonetz		peaty meadow solonetz with saline subsoil	meadow soil with saline subsoil	meadow soil with saline subsoil	meadow soil with saline subsoil
6. Natraquoll		Natraquoll	Natraquoll	Haplaquoll	Haplaquoll
7. none		none	slight sheet erosion	none	none
8. none		none	slight	none	none

Remarks: * pH and EC were measured in freshly prepared suspension with 1:5 soil:water ratio; ** sample number in brackets

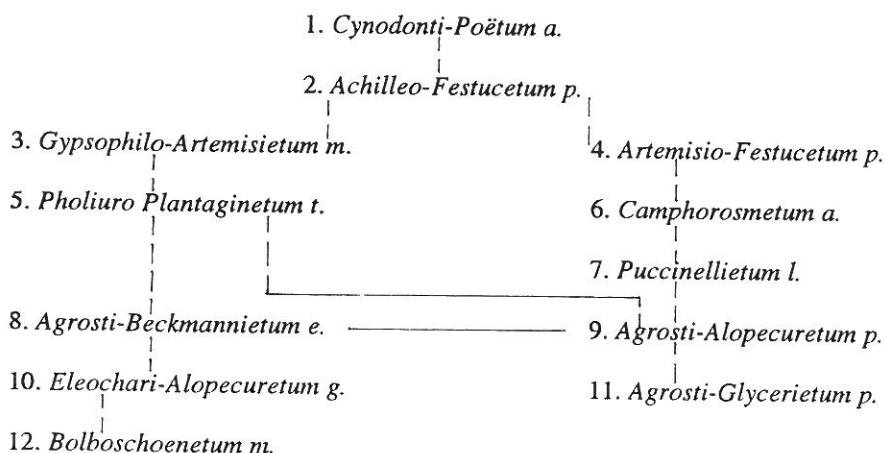


Fig. 1.

Succession of certain plant associations in Hortobágy, after VARGA (1984).
 The succession 2 - 3 - 5 is a typical example of sheet erosion and the succession 4 - 6 - 7 is an example of bank erosion.

Materials and Methods

Aerial photography

The aerial photograph was recorded at Nyírólapos, Hortobágy on 9th August, 1988 at an elevation of 400 m, with an objective of 80 mm focuslength on AGFACOLOR AERO INFRACOLOR IC material. The original scale was 1:5,000. The basis of the interpretation was a montage of colour prints on a scale of 1:1,000. The boundary perception in aerial photo interpretation depended on the pattern and intensity of the photograph and was considered very sensitive for local inhomogeneity.

Delineation of the patches

In the first phase of the interpretation the spots visible on the basis of differences in colour and pattern in the aerial photograph were delimited. The spots obtained in this way were coded by an abbreviation denoting a colour, e.g. BV: brownish red. The spots having the same colour but differing in pattern were distinguished by an extra number such as K1 and K2. The most problematic part of the coding was the fact that the density within each photograph varied considerably: some parts of the photograph were much darker than the

others. The hues caused by this phenomenon were not intended to be taken into consideration during coding.

In the second phase of the interpretation of the photograph our objective was to identify the different spots and different types of codes as different types of vegetation cover. The vegetation types were determined during a thorough field survey. Special care was taken not to record merely plant associations, but instead to typify the degradation status of the area by the use of well defined vegetation types.

As the resolution was only 1-2 m in aerial photo interpretation, it resulted in many types of vegetation and consequently the characterization of the vegetation types was detailed enough.

Results

It was concluded that the vegetation types reflected the basic vegetation (dry grassland, meadow, marsh), the organizational forms (homogeneous vegetation, smooth transition, complex) and the disturbance and abundance of weeds. The most important processes determining the present degradation status are the water erosion of the eluvial A horizon, grazing, trampling, the fluctuation of the groundwater level and other anthropogenic effects. The vegetation types distinguished and their degradation status, which are shown in Fig. 2 were the following:

- R4: Extremely disturbed vegetation type with high dry stalks, weeds, *Daucus carota* and *Cichorium intybus*. This is presumably a transition from degraded slightly salt-affected grassland into *Cynodonti-Poëtum a.* It shows traces of overgrazing and trampling.
- R2: Short *Achilleo-Festucetum p.*, a kind of transition into *Cynodonti-Poëtum a.* Besides *Koeleria glauca* and *Agropyron repens*, *Salvia pratensis* and *Althaea officinalis* are also found. In the lighter parts *Bromus m.* is widespread, and in the darker parts disturbance is heavy.
- M1: Disturbed patch of *Cynodonti-Poëtum a.* on a higher relief, surrounded by *Achilleo-Festucetum p.* It is disturbed and contains *Koeleria glauca*.
- KZ2: *Achilleo-Festucetum pseudovinae* with plenty of *Bromus mollis* and *Koeleria glauca*.
- M6: *Achilleo-Festucetum p.* with plenty of *Bromus m.*, lying on relatively higher places. In contrast to the other transitions of *Agrosti-Alopecuretum p.*, in this case the species of the meadow appear individually.
- T2: Usually thick *Artemisio-Festucetum p.*, but also contains patches of *Agrosti-alopepuretum p.* and smaller patches of *Agropyron repens* and *Alopecurus pratensis*. As there is only a slight difference between the reliefs of *Artemisio-Festucetum p.* and *Agrosti-Alopecuretum p.* the transition between

the two vegetation types is gradual and as a consequence of drying, the *Agropyron repens* has spread further.

- K3: Similar to K2, it has very homogeneous, even vegetation, which is presumably the product of sheet erosion, the only form of erosion here.

- Z3: *Artemisio-Festucetum pseudovinae* with thinning cover, representing a transition between *Artemisio-Festucetum p.* and the associations of streamlets. It is the product of sheet erosion, as is indicated by the large coverage of *Nostoc commune* and *Camphorosma annua* in the deeper patches. The location of this vegetation type is intermediate between the extremely heterogeneous erosional forms of bank erosion and the deep-lying, relatively homogeneous *Pholiuro-Plantaginetum l.*

- R3: *Artemisio-Festucetum p.* resembling K2, with plenty of *Bromus mollis* and *Hordeum hystris*. It shows heavy previous trampling and local bank erosion.

- K2: High *Artemisio-Festucetum p.* with plenty of *Bromus mollis* and *Cynodon dactylon*. The red colour of the montage suggests thick vegetation. On higher places *Achillea sp.* is also widespread. The gaps between the main species are filled by moss, and by *Nostoc commune* on lower places. There are several pink patches of 3-6 m diameter where there is less *Bromus m.*, the grass is smaller and the coverage of *Artemisia maritima* is greater. This type represents the lower ones among those types of union of surface water as it is directly joined to *Pholiuro-Plantaginetum t.*, but also contains patches of *Agrosti-Alopecuretum p.* and *Achilleo-Festucetum p.*, and very few individuals of *Cynodonti-Poëtum a.* It is a transitional type that is located between the relatively high side of the stream and the inner shallow streamlet. The erosional forms comprise bank erosion and traces of sheet erosion in a complex manner.

- M2: This is a transition between Z1 and Z2, with patches of *Euphorbia cyparissias* and *Hordeum hystris*, plenty of dry stalks of high weeds, tussocks, and plenty of *Artemisia maritima*. The two vegetation types, Z1 and Z2 are quite distinct, but on the scale of the aerial photo this is not obvious. Like Z2 it also indicates a small change in the relief. *Artemisio-Festucetum p.* and *Agrosti-Alopecuretum p.* turn into each other not sharply, but in an island-like manner. Regarding the species, the transition is continuous. The present direction of succession favours the spread of *Artemisia maritima*. The heavy disturbance mentioned in the case of R4 is also observable in this type.

- A2: *Agrosti-Alopecuretum pratensis*, with continuous transition into Z2. It is the characteristic product of sheet erosion.

- M5: Transition of R3 into Z1, i.e. the trampled transition of *Artemisio-Festucetum p.* with *Hordeum hystris* and *Bromus mollis* into typical *Agrosti-Alopecuretum p.*

- M4: Composite of *Artemisio-Festucetum pseudovinae* with *Hordeum hystris* and *Agrosti-Alopecuretum p.* as a consequence of extreme trampling.

- R: Similar to R3, it has *Achilleo-Festucetum p.* on the higher places, while on the boundaries it has meadow-like, much weaker, variegated vegetation.

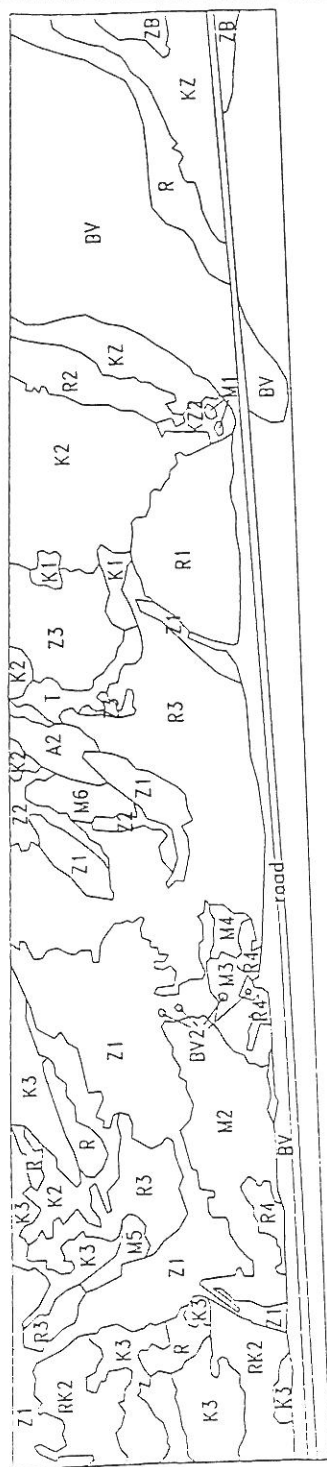


Fig. 2
Patches of vegetation distinguished on the basis of aerial photographs and field surveys

Code	Description	Degradation status
<i>Salvia-Festucetum sulcateae</i> and its variations		
R4	Dominant sp <i>Daucus</i> c., <i>Hordeum</i> h., <i>Cichorium</i> i.	Strong disturbance
R2	Transitional vegetation between <i>Achilleo-Festucetum</i> p. and <i>Salvia-Festucetum</i> s.	Disturbance
M1	<i>Salvia-Festucetum</i> s.	Trampling and overgrazing
<i>Achilleo-Festucetum pseudovinae</i> and its variations		
KZ2	<i>Achilleo-Festucetum</i> p. with <i>Koeleria</i> c.	No degradation
M6	<i>Achilleo-Festucetum</i> p. with meadow spp.	No degradation
<i>Artemisio-Festucetum pseudovinae</i> and its variations		
Z2	Thick <i>Artemisio-Festucetum</i> p.	No degradation
K3	Homogeneous <i>Artemisio-Festucetum</i> p.	No degradation
Z3	Thinning <i>Artemisio-Festucetum</i> p.	Sheet erosion, trampling and grazing

R3	<i>Artemisio-Festucetum p.</i> with <i>Bromus m.</i> and <i>Hordeum h.</i>	Bank erosion, trampling and grazing
K2	<i>Artemisio-Festucetum p.</i> with <i>Cynodon d.</i>	Bank and sheet erosion
M2	Vegetation transitional between <i>Artemisio-Festucetum p.</i> and tussocky form of <i>Agrosti-Alopecuretum p.</i>	In some places disturbance, drying out
A2	Vegetation transitional between <i>Artemisio-Festucetum p.</i> and <i>Agrosti-Alopecuretum p.</i>	Sheet erosion
M5	Weedy vegetation transitional between <i>Artemisio-Festucetum p.</i> and <i>Agrosti-Alopecuretum p.</i>	Trampling
M4	Weedy mosaic-like composite of <i>Artemisio-Festucetum p.</i> and <i>Agrosti-Alopecuretum p.</i>	Trampling
R	Mosaic-like composite of <i>Achilleo-Festucetum p.</i> , <i>Artemisio-Festucetum p.</i> , <i>Agrosti-Alopecuretum p.</i> and in some places bare spots	Local bank erosion
R1	Mosaic-like composite of <i>Achilleo-Festucetum p.</i> , <i>Artemisio-Festucetum p.</i> , and bare spots	Bank erosion, trampling and grazing
T	Mosaic-like composite of the vegetation of bank erosion	Bank erosion
RK2	Mosaic-like composite of <i>Artemisio-Festucetum p.</i> and <i>Camphorosmetum a.</i>	In some places strong erosion
<i>Camphorosmetum annuae</i> and its variations		
KZ	<i>Camphorosmetum a.</i>	Strong erosion on slopes
I	Bare spot	Fast, strong erosion
<i>Pholiuro-Plantaginietum tenuiflorae</i>		
K1	<i>Pholiuro-Plantaginietum t.</i>	Alkalinization, drying out
<i>Agrosti-Alopecuretum pratensis</i>		
H3	<i>Agrosti-Alopecuretum p.</i> with patches of <i>Hordeum h.</i>	Trampling and grazing
Z1	Tussocky <i>Agrosti-Alopecuretum p.</i>	Locally trampling
<i>Bolboschoenetum maritimae</i>		
BV2	<i>Bolboschoenetum m.</i>	No degradation
<i>Scirpo-Phragmitetum</i>		
BV	<i>Scirpo-Phragmitetum</i>	No degradation
ZB	<i>Scirpo-Phragmitetum</i> in higher position	No degradation

- R1: Similar to K2, but it has many patches of *Achilleo-Festucetum p.* and bare spots in a complex manner. It resembles T, but the scale of changes is much smaller here.

- T: The most heterogeneous area, a band with formations of bank erosion, streamlets and bare spots. On the top of the banks *Artemisio-Festucetum p.* with *Camphorosma annua* and mosses. This vegetation type can be considered as a complex of others and is located in a narrow band on the side of earlier streams and streamlets packed tightly together.

- RK2: A complex of R and K2, preserving the properties of both.

- KZ: *Camphorosmetum annuae* independent of bank erosion, located between *Scirpo-Phragmitetum c.* and *Achilleo-Festucetum p.* Inside *Camphorosmetum a.* there is a band of bare spots following the boundary of *Scirpo-Phragmitetum c.* It is the product of heavy erosion tending towards the salt-affected marsh from the direction of a higher relief. This form of erosion affects a relatively large area and bare spots are found at sites with the heaviest erosion.

- I: Bare spots. The occurrence of this type is limited almost completely to the Eastern part of the area, where the differences of relief are greater, and therefore indicates that the bare spots are produced by fast, heavy phenomena of erosion. The characteristic species of the vegetation type is *Camphorosma annua*, but it has very low coverage. Consequently, the coverage of white amorphous silica is easily recognizable in the grassland and also on the aerial photograph. The patches have not been delineated on the map since the coverage of the individual patches was very small, inside patches of R1 and T.

- K1: *Pholiuro-Plantaginetum tenuifoliae* with plenty of *Artemisia maritima*, a spot where several small surface streamlets unite. It contains *Pholiurus pannonicus*, *Alopecurus geniculatus*, *Puccinellia limosa* and *Plantago tenuifolia*. It may be derived from *Agrosti-Alopecuretum p.* as a consequence of drying and alkalization.

- M3: Like Z1, but with many patches of *Hordeum hystrix*, and it indicates heavy previous trampling.

- Z1: Tussocky *Agrosti-Alopecoretum pratensis* with *Agrostis alba*, *Alopecurus pratensis*, *Beckmannia eruciformis*, *Agropyron repens* and *Glyceria fluitans*.

- BV2: *Bolboschoenetum maritimi*, which is found mainly isolated inside *Artemisio-Festucetum p.* patches, as circles 1-2 m in diameters. The association is made up of *Bolboschoenus maritimus* with *Schoenoplectus tabernaemontani* as the accompanying species. These patches do not dry out even in summer, because several canals and brooklets flow into them.

- BV: *Scirpo-Phragmitetum communis*. On the edges of compact patches *Bolboschoenetum m.* (and occasionally *Agrosti-Alopecuretum p.*) is found. The species composition reflects the effect of a salt-affected environment. The dominant species are *Phragmites communis* and *Typha angustifolia*, but *Cirsium brachycephalum* and *Schoenoplectus lacustris* are also present. The patches of BV are found in a contiguous marshy part and parallel to the road in

a long band (as a consequence of the construction of the road and the canal by its side). These patches are the deepest ones in the area.

- ZB: Similar to BV but in a higher lying position and not so thick.

Conclusions

Aerial photographs are valuable sources of information during the delineation of the vegetation types of solonetzic grasslands, and when these types can be correlated with soil types, also during the delineation of soil types.

Furthermore, aerial photographs are sensitive for the delineation of special erosion forms, such as bank erosion in solonetzic grasslands.

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