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ALLOCATION OF SOIL RECLAIMING MATERIAL BASED ON DIGITAL PROCESSING OF AERIAL PHOTOGRAPH

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KEY WORDS: aerial photograph, digital processing, sampling plan, estimation error, salt-affected soil, soil reclamation, gypsum requirement, Hungary

ABSTRACT

Precision farming has two requirements, such as i) correct dosage of agricultural materials realized at ii) the exact location in the plot where these are needed. Our objective was to introduce the direct use of remotely sensed images into the practice of soil reclamation as a source of information on i) the probable dosage of required amendment and ii) precise location of reclaiming materials.
The remotely sensed image was used in two phases, for the selection of optimal soil sampling plan to reclaim the plot and for the compilation of actual plan of reclamation.
The basic material of the study was a panchromatic aerial photograph on a sodic plot with patches of higher sodium-affection.
As a first step the relationship between gypsum requierement and the intensity of the aerial photograph was established. It turned out to be linear and therefore the aerial photograph was used directly for the analysis of alternative sampling plans.
As a test of the utility of sampling plans, a set of potential sampling points were used for the interpolation of the original aerial photograph and the precision of the interpolation was measured by the sum of squares of the differences between the original and the interpolated photographs.
The optimal sampling plan was selected accordingly and the field sampling, which was carried out for its test, confirmed the previous selection.

INTRODUCTION

All over the world large tracts of sodic soils receive gypsum as reclaiming material. We do not describe its mechanism here, just make reference to that the calcium ions released upon the dissolution of gypsum replace the harmful sodium ions and create favourable conditions for the soil solute transport and plant growth (McBride, 1994).
The present status of within-plot reclamation of salt-affected soils in Hungary does not follow the technological advancements (MSZ 9693/1-77). When there is a special map series of the status of salt accumulation, it is perfectly suitable for the production. If it is not available, the corresponding national standard prescribes the reclamation based on average samples. In view of the mosaic pattern of such lands the use of average samples easily can result in large sub- or overestimation of the necessary dosage of reclaiming materials. This mosaic pattern of the salt-affected soils is manifested in several properties of the soil, most importantly its natural vegetation (Csillag et al., 1993, Kertész and Tóth, 1994, Tóth and Kertész, 1996, Tóth and Pásztor, 1996, van Meirvenne et al., 1996). On croplands, when there is no vegetation cover the areas with different salt accumulation status can often be distinguished on remotely sensed images (aerial photograph, satellite images) (Metternicht and Zinck, 1996, Tóth et al., 1991a and b) based on the surface features of the soil.
Our objective was to improve the reclamation of salt-affected soils with the direct use of aerial photographs.

MATERIALS AND METHODS

Preliminary sampling and its evaluation

In order to describe the character of the relationship between the intensity of aerial photograph and the gypsum requirement, on a sampling route representing the intensity distribution of the aerial photograph (Fig 1), we collected soil samples at 13 points, and measured field bulk electric conductivity in situ at another 50 points. The location and elevation of the sampling points was recorded with a field station, therefore we could find out the intensity from the aerial photograph.

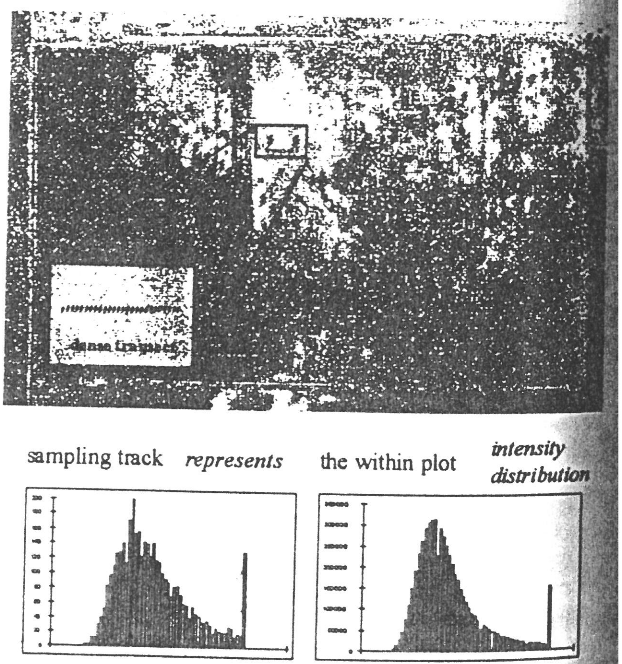

Fig 1. Airborne image of the sample plot with the preliminary sample sites

The preliminary sampling showed that there is linear relationship between the gypsum requirement (GR) determined in the laboratory and the intensity value of the pixels, and these results suggested that the aerial photograph could be used directly for the realization of the sampling plan.

Sampling strata

The sampling strata were distinguished based on the brightness (intensity) of the digital image scanned from a panchromatic negative of the aerial photograph.

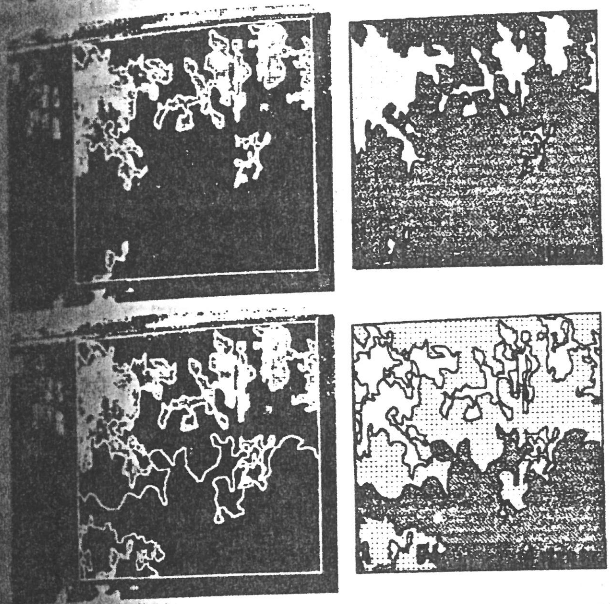

Fig 2. The sampling strata

First we examined the intensity distribution of the image. On the histogram we identified the modals according to 2 and 4 strata (Fig 2). We determined the area of the individual strata, and the average intensity inside the respective strata, which values were used for the weighted sampling plans. The area was about 50 ha large, and since Hungarian standards for the reclamation of salt-affected soils prescribe one sample each 5 ha, our minimal sample size was 10. It was increased by 2, 4, 8 times in order to increase the spatial representation.

In the case of random sampling, the sampling points were allocated independently from the information content of the image.

In one series of sampling plans we intended to express the work/investment requirement of gypsuming, so the number of sampling points was weighted by the average intensity values of the sampling strata. Compared to the non-weighted sampling plan, now we had relatively more sampling points in the high-intensity strata in order to increase the precision of predicting gypsum requirement in these strata. The number of sampling points determined is shown in Table 1.

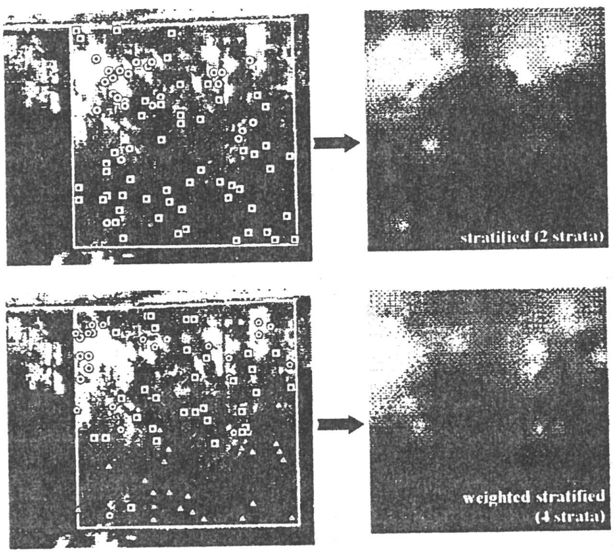

Fig 3. Comparison of original and interpolated images based on sample size of 80

The sampling plans were tested by Monte-Carlo simulation. We generated completely random spatial distribution of 10, 20, 40, 80 points, which are the realizations of any homogeneous spatial Poisson point process.

Table 1. The tested sampling plans

Sampling plan / Sampling size in stratum				4-strata				2-strata	
Sample size	1.	2.	3.	4.		1-2.	3-4.		
Total sample	134		9	30	50	45		39	95
Sampling plans:									
Weighted by intensity									
	80		6	20	32	22		26	54
	40		3	10	16	11		13	27
	20		2	5	8	5		7	13
	10		1	2	4	3		3	7
Non weighted									
	80		3	14	33	30		17	63
	40		2	7	16	15		9	31
	20		1	3	8	8		4	16
	10		0	2	4	4		2	8

We wanted to test the precision of the individual sampling plans. Therefore we determined the intensity of the image in the simulated sampling points, actually the average of the pixels found in its 50 cm radius neighborhood. Then this value was related to the given geometrical point and the intensity values were interpolated for the image with inverse-distance-

square method in the original pixel resolution of the image. The difference between the original pixel values and the interpolated pixel values pixelwise was expressed by the sum of the square of the differences. The smaller its value, the preciser is the interpolated image compared to the original image. This comparison was realized 20 times for each sampling plan (Fig 3).
Based on the comparisons, we selected a sampling plan, which was tested in the field, but due to difficulties in the precise field localization, we selected more or less homogeneous patches not smaller than 3 m for sampling.

Testing of field sampling plan

The most important point in the test of the sampling plans was to provide simple and practically applicable plans for the everyday routine of soil reclamation. Therefore the stratification of the samples was made only on the basis of one variable, the intensity of the image, and we examined the estimation precision of only one chemical variable, that of gypsum requirement. Furthermore we used the simplest possible estimation technique, the averaging. Therefore all the tested gypsum requirement estimations can immediately utilized.
As shown in Table 1 there were 134 samples, which have been stratified into either 2 or 4 strata. First we used analysis of variance to find out whether the sampling strata differred regarding the GR (Table 2).

Table 2. Results of the analysis of variance of Gypsum Requirement (GR) by sampling strata

Stratum	Mean GR (t/ha)	St. Dev.	Sample size	Significance
1	7.26	2.42	9	<0.001
2	5.33	2.14	30	
3	3.16	1.89	50	
4	2.08	1.78	45	
1-2	5.78	2.33	39	<0.001
3-4	2.65	1.90	95	

Later the sample of 134 samples was considered to be the full sample population, and we collected small samples in order to test the sampling plans of Table 1. There were altogether 16 such sampling plans tested.

RESULTS AND DISCUSSIONS

Correlation between gypsum requirement and intensity of the image

Based on 134 samples, the correlation fully justified our preliminary assumption, and proved that the intensity strata can be used directly for the estimation of GR (Fig 4).

Results of the testing of field sampling plans

The sampling plans were evaluated regarding GR. The sampling strata showed strongly significant difference in the average values of elevation above sea level, local intensity an intensity averaged for the neighborhood, as well as GR.

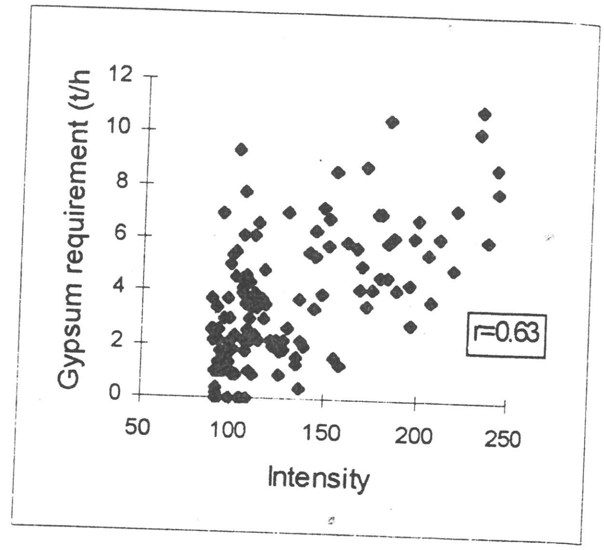

Fig 4. Correlation between the intensity of aerial photograph and the gypsum requirement

The errors of the conclusions which can be drawn from the sampling plan is shown on Table 3. This table shows in how many samplings we can draw erroneous conclusions from 7-7 random samples. In the left half of the table the first criterion (in the 1-2. sampling strata GR is larger than 4 t/ha, in 3-4 strata it is less) was used, in the right half we used the first and second one (GR diminishes from stratum 1 to stratum 4). The relative estimation variances and the estimation errors are shown on Fig 5.

Table 3 The erroneous conclusions which can be drawn from the sampling plans

criteria	1. criterion		1. and 2.	
Sample size strata	4-strata	2-strata	4-strata	2-
Weighted by intensity				
80	-	-	-	-
40	-	-	2	-
20	1	-	3	-
10	4	1	5	1
Non weighted				
80	-	-	-	-
40	-	-	1	-
20	2	1	4	1
10	1	1	4	1

The following conclusions were drawn from it
a) the precision of estimation decreases with the reduction of sample size from 80 to 20 generally, that is the relative estimation variance and estimation errors increase. This increase is not steady, but gets larger with smaller sample size. There is no detectable difference between the 40 and 80 sample size in estimation variance.

b) With the decrease of sample size, the differences between the relative variances of estimations, corresponding to separate sampling plans, do also decrease. The reason for this is that the total sample, which was used for the calculations of the error of separate sampling plans, does contain the data selected for the testing of the sampling plans, and in case of large sample sizes the overlap between the two data sets and samples is larger.

c) There is not significant difference between the weighted and non weighted sampling plans.

d) The estimation errors decrease from sampling stratum 1 to stratum 4, but the errors of strata 3 and 4 are practically the same. The reason for the decrease of error is the decrease in GR.

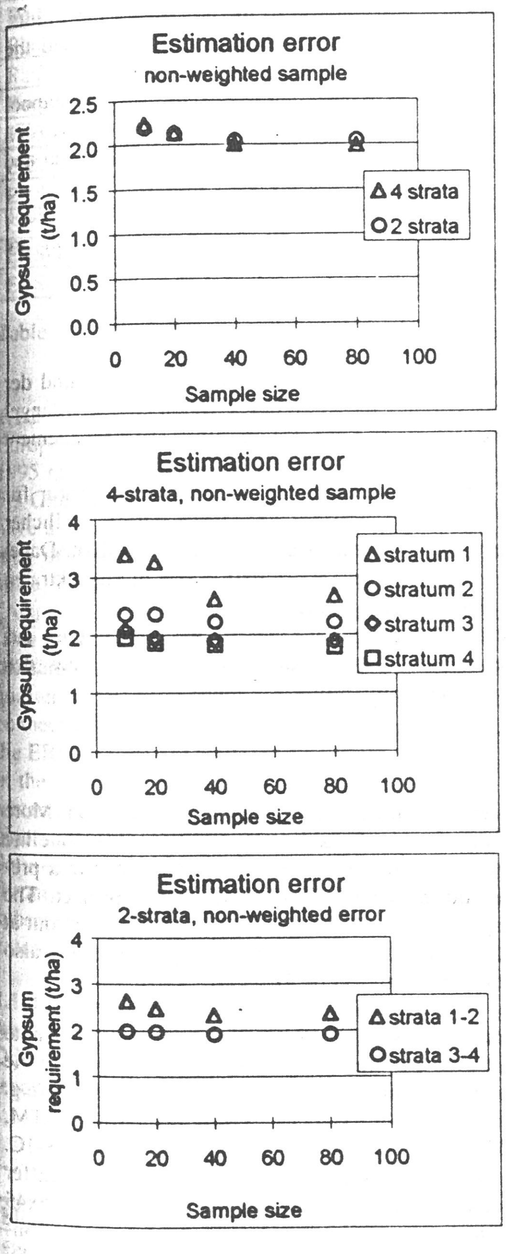

Figure 5. Relative estimation variances and estimation errors of applying the field sampling plans

CONCLUSIONS

Our criteria for the field sampling plan are the following:

a) The conclusions drawn from the sampling plan should be right.

b) The sample size should be minimal.

c) The sampling plan should be the simplest.

Criterion a) excludes all sampling plans that result in erroneous conclusion based on Table 3, and criterion 2 excludes the sample size of 80. The third criterion is the weakest, since the difficulty of obtaining and evaluating an aerial photograph is much larger than that of its stratification, and weighting by intensity. Based on these, we suggest the use of 2-strata sampling plan with sample size of 20. There was not significant difference between the weighted and non weighted sampling plans. In that case when there are few samples falling into the sampling strata with large intensity, based on spatial statistical considerations, we suggest the use of weighted sampling plan.

The suggested technique for the preparation of allocating plans of reclaiming materials is applicable not only for gypsum, but for other materials as well, if there is linear relationship between the intensity of aerial photograph and the required amount of reclaiming material.

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