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Method of Determining Relations between the Extent of Damage in Farm Crops, Big Game Numbers, and Environmental Conditions

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With the use of statistical methods it is possible to forecast the extent of damage in farm crops done by big game (red deer and wild boars). Mathematical model for a definite number of animals in definite ecological environment and on definite area was solved with the aid of multiple regression analysis. Studies, carried out during years 1973—1975, included 23 lowland forest districts situated within the Silesian Land. Data collected in each forest district concerned the size of animal populations, information on environmental characters related with their behaviour, as well as the area and value of damage inflicted in farm crops. There were obtained regression equations illustrating economic and ecological aspects of the situation prevailing in hunting grounds. Resulting from the model characters at most affecting both the area damaged and the value of compensation were: (1) numbers of wild boars, (2) contribution of the fresh mixed coniferous forest in the total study area, (3) area proportion of the fresh coniferous forest, (4) area of forest stands with the prevalence of pine (*Pinus silvestris* L.) and larch (*Larix decidua* Mill.), (5) area of Ib (11—20 years old) and IIa (21—30 years old) age-classes of forest stands, and (6) size of the forest area within the unit studied. The model may be useful in manipulating numbers of individual populations: It is also helpful in the selection of habitat features, since it states which of them cooperate in the process of damage formation. It yields also numerous indications for further research.

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1. INTRODUCTION

National economy suffers annually heavy losses inflicted by the big game (moose, red-, fallow deer, and wild boars) feeding on farmland adjoining forests. This damage cannot be avoided entirely, but can be reduced. This is the direction of research work undertaken (Mackin, 1970; Ortwein, 1975; Andrzejewski & Jezierski, 1978). It may be suggested that hunting harvest is the most important regulator of game numbers. On the other hand game management had not developed optimal indices of the numbers of game animal species which caused the damage. Polish standards of food carrying capacity of hunting reviers based on methods of site classification do not consider numerous factors interacting between animal populations and their environment

(Dzięciołowski, 1976). While accepting as a starting point the criterion of food carrying capacity of forest habitat (Dzięciołowski, 1970) they neglect numerous other significant characters which may be of decissive importance for various phenomena of population performance, among other things for the process of damage formation. Studies on the identification or density of herbivore populations are being undertaken in various countries. European studies are based primarily on scoring sites (Ueckermann, 1952; Müller, 1962; Neumann, 1963) or on the appraisal of resources of natural food in various habitat types (Padaiga, 1968). On the other hand American researchers (Davis, 1967; Hayne, 1969) sought the solution of the problem in optimisation techniques. However, none of the techniques suggested found full application under Polish conditions.

Assumption that the damage caused by game in farm crops is the function of environmental pressure upon game and that these relationships may be expressed in the form of a mathematical model constituted the starting point for this paper. The first aim of the studies was thus the construction of a model including statistical relationships between selected populations of big game and their environment presented in the form of strictly defined characters. Statistical multivariant analysis, providing a background for the development of procedure predicting game response under various spatial conditions, was the successive goal. The extent of agricultural damage done by game was the measure of this response.

As a final effect this enabled the determination of diagnostic features, which provided the best basis for predicting damage. It yields also the possibility of undertaking attempts of affecting, through selected factors (explanatory variables), upon outcome variable (damage) interesting for us, and thus practically upon the reduction of the compensation paid.

2. STUDY AREA, MATERIAL, AND PROCEDURES

Data, collected during years 1973—1975 in 23 lowland forest districts of the Provincial Board of State Forests in Wrocław, provided empirical material. These cover one contiguous region situated mainly in the Silesian Land, in districts of: Lower Silesian Plain, Lower Silesian Hills, and partially Sudety Tectonic Foreland (Mroczkiewicz, 1952). The Land is within the range of our all more important forest tree species, many of which have here their natural boundaries of distribution. Pine (*Pinus silvestris* L.) prevails in the species composition of stands in most forest districts, while from among deciduous species — both oak species (*Quercus robur* L. and *Quercus petraea* Liebl.).

The distribution of forest site types is rather irregular here. The fresh coniferous forest is most common, particularly in the district of the Lower

Silesian Plain (Lower, Silesian Coniferous Forests), while the fresh mixed deciduous forests prevail in the district of the Sudety Tectonic Foreland and partially — in Lower Silesian Hills. Big forest tracts, called Lower Silesian Coniferous Forests with the area of circa 3,150 km^2 occur to the north from the line: Pieńsk — Bolesławiec — Chojnów — Legnica — Prochowice. Smaller tracts are to be found in the Trzebnica Ridge ,in the Barycz River catchment, in the Odra River valley, between Odra and Widawa Rivers, to the north-east from Oława, and on hills of the Sudety Tectonic Foreland.

On the other hand in the Silesian Lowland in part of the Wrocław Plain only small forest tracts strongly altered by the artificial introduction of spruce, occur.

Table 1
Area of damage done by game and compensation paid according to protocols.

Year	Reduces area of damage, ha	Cereals, rape, lupin		Root and tuber crops, maize		Total compensation, thous. zloties
		Reduced area, ha	Compensation thous. zloties	Reduced area, ha	Compensation thous. zloties	
1973	356.23	258.62	2.366	97.61	1.758	4.267
1974	511.76	378.09	3.874	133.67	2.194	6.549
1975	540.12	366.64	3.960	173.48	3.074	7.414

Table 2
Numbers of big game according to winter census.

Year	Red deer	Fallow deer	Mouflons	Wild boars
1973	1.589	215	40	1.604
1974	1.618	224	40	1.788
1975	1.754	223	40	1.888

Table 3 contains the closer characteristics of the forest districts constituting the study area. Agricultural lands, on which damage done by game has been appraised, were of state, cooperative, and private ownership. Table 1 gives the area of damage and amounts of compensations paid, while table 2 — the numbers of big game.

Each forest district was described with 39 characters classed as outcome and explanatory variables.

Outcome variables y_i represent the reduced area of damage and value of the compensation paid. Explanatory variables x_i include: numbers of red deer and wild boars during the winter census of game and during the occurrence of the most severe damage, total and forest area of forest district, area of individual forest site types, area according to tree species prevalence, area according to age-classes of forest stands, degree of the concentration of forest tracts, length of boundaries of forest tracts, length of boundaries of water, fodder from game food patches during winter and summer, area of winter cereals, area of forest meadows and pastures, and that area of undergrowth. Since the value of an ecolo-

Table 3
Input data about forest districts. No and numerical value of a

Forest district	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{14}	x_{17}
1. Bierutów	64	70	76	85	5280	10280	1740	3830
2. Bolesławiec	71	88	74	138	58900	34120	22780	3860
3. Chocianów	139	139	111	111	40800	30120	16880	2840
4. Dębno	131	147	96	127	61700	16890	3120	7520
5. Góra Śląska	87	110	104	135	60500	14250	6680	3440
6. Grochowo	136	158	99	80	50500	13590	4020	6030
7. Henryków	6	23	19	60	125400	10820	—	—
8. Jawor	197	210	79	100	43200	7310	—	560
9. Oława	21	20	35	30	77700	9370	1290	1390
10. Legnica	28	30	48	55	94900	15280	3450	5880
11. Lubin	40	48	60	76	60900	16960	5860	7050
12. Lwówek Śląski	—	—	65	98	40600	8480	30	2350
13. Miękinia	58	58	20	20	111600	9880	490	1060
14. Milicz	137	170	132	223	50800	14870	2610	6480
15. Oborniki Śląskie	19	23	65	73	49500	12650	670	5750
16. Osiecznica	105	110	47	50	19900	15390	8140	1500
17. Pieńsk	74	70	84	80	66000	12970	3430	2720
18. Ruszów	130	134	21	26	19500	16160	7260	760
19. Sułów	173	239	95	210	34800	13900	4640	3270
20. Syców	135	155	114	175	50500	14050	2700	5310
21. Węgliniec	73	75	68	75	52500	15610	4120	1860
22. Żmigród	163	185	79	161	38500	10950	970	2330
23. Chojnów (Złotoryja)	4	5	13	18	52000	9370	3480	2320

gical model does not consist in an accurate duplication of reality, it has been assumed that characters (variables) accepted are simplifications including integral processes occurring in the ecosystems studied. They illustrate also fundamental requirements of game connected with its nutrition, breeding, and shelter. Values of some characters could be defined directly from data contained in programmes of forest management and other statistical materials available in forest district offices, as well as from the inquiry developed and distributed among them. Values of remaining characters required adequate computations and transformations. And so:

1. Game numbers. Game numbers at the moment of winter census have been determined with the aid of inquiry. The inquiry was extended to include numbers at the moment of the highest intensity of damage in agriculture. These numbers frequently unrelated to the size of the breeding stock, may decidedly affect the extent of damage. Red deer and wild boar, two species inflicting the most serious damage in farm crops, were the object of studies. Fallow deer and mouflons, occurring in some forest districts and equally burdensome for farm crops as previously mentioned species, were converted into red deer numbers.

Conversion factor, according to which 1 red deer = 1.5 fallow deer and = 2 mouflons, was applied.

2. Variable describing the degree of the concentration of forest tracts. It illustrates spatial possibilities of game migration among forests conditioned by the course of boundaries and distances between tracts.

The formula developed for the determination of this character is following:

variable in the accepted set of characters. Values of characters from 1973.

x_{25}	x_{26}	x_{28}	x_{29}	x_{30}	x_{32}	x_{33}	x_{35}	x_{36}	x_{38}	x_{39}
6970	440	1690	4560	1670	0.090285	2619	10345	9715	461	5140
31840	280	1930	18270	8740	0.028929	3423	11505	14560	335	1020
27070	520	2810	12600	9090	0.000588	2460	17240	22710	350	2630
11520	250	4140	6520	4030	0.061489	4502	15310	27015	535	13500
11030	260	1800	3930	4160	0.026168	3734	20780	23520	343	1700
11990	370	970	5080	2390	0.073675	2764	19365	81675	343	8700
1670	2490	6140	3760	1730	0.754501	4030	3585	47820	201	9300
710	2500	3880	2890	750	1.750641	1883	60560	34650	270	7310
4330	370	3700	3990	1620	0.257787	2199	2165	16255	530	3280
10370	200	4110	4710	4410	0.078496	4033	7750	12850	383	10700
13780	250	2410	5510	4600	0.041184	5060	17750	24140	224	12720
3900	2200	2030	3150	1790	0.132418	3545	9975	6750	342	5100
2430	430	5150	4400	1270	0.600648	4085	7385	12750	562	3160
12170	450	1720	5450	3270	0.020565	4659	77985	76490	431	2230
8350	510	3240	5100	2170	0.151108	3817	24695	42850	234	7600
14070	310	990	7790	5150	0	1418	7330	8520	485	1540
8400	1810	2580	4510	3810	0.479118	3300	13200	25060	351	1950
14960	200	870	7150	4310	0	1300	2270	21795	448	1940
11570	390	1570	5280	2990	0.097318	2120	12970	35420	407	5560
11160	1040	1450	5140	2830	0.048337	3735	7630	26725	327	3090
9740	3500	2140	5550	3890	0.211247	4023	8010	4625	583	400
6350	320	2400	4250	2580	0.024204	2958	16170	42610	523	2960
7660	410	1080	2880	2210	0.035854	2696	460	12105	206	1690

$$K = \frac{L^2 \ (p-1)}{P}$$

where:

K = concentration coefficient,
L = weighted mean distance between individual forest tracts arranged into one open diagram,
p = number of tracts,
P = forest area of the district (total area of tracts with individual size exceeding 100 ha).

3. Length of the boundary line of forest tracts, water courses and reservoirs. It has been measured on official maps of forest districts in the scale of 1 : 5000, the length of a water course being the total of length of its both banks. In search of water the game covers at time considerable distances. This is why the study and measurement area was extended to the distance of 2 km from boundaries of forest tracts. This principle was a priori assumed.

4. Fodder and food from game patches. Nutritive value of fodder offered to game animals or of food grown on patches was determined on the basis of its energetic value expressed in oat units. Indices were taken from tables of "nutritive value of fodders" applied in animal husbandry for various animal groups. Value of this character was divided into summer (April 1 — September 30) and winter (October 1 — March 31) period due to slightly different importance ascribed to supplemental feeding during each of these seasons.

Complete set of characters (39), prepared for the set of regressions, was too numerous considering the small sample size (23 units). Their definite selection, both via the statistical analysis on the background of correlations occurring and through a substantial analysis based on the appraisal of the usefulness of character for the description of the phenomenon studied, has been done before the application of the procedure. Such a selection resulted from the assumption that in the analysis of multiple regression characters are not correlated directly.

The impact of a given factor upon damage is not examined separately, but the effect of a set of characters, which only in the same arrangement affect the outcome variable, is being studied. The selected set of 21 characters included:

— outcome variables:
y_1 — reduced area of damage, in ha;
y_2 — value of total compensation paid, in thous, zloties;
— explanatory variables:
x_7 — numbers of red deer at a time of winter census, in pieces;
x_8 — numers of red deer at a time of the most severe damage, in pieces;
x_9 — numbers of wild boars at a time of winter census, in pieces;
x_{10} — numbers of wild boars at a time of the most severe damage, in pieces;
x_{11} — total area of the forest district, in ha;
x_{12} — forest area of the forest district, in ha;
x_{14} — area of the fresh coniferous forest, in ha;
x_{17} — area of the mixed fresh coniferous forest, in ha;
x_{25} — area of stands with predominance of pine and larch, in ha;
x_{26} — area of stands with predominance of spruce, fir, Douglas-fir, in ha;
x_{28} — area of stands with a predominance of "remaining deciduous species", in ha;
x_{29} — area of scattered woodland, gaps, cuts, stands in the Ia (1—10 yrs old), V (80—100 yrs old) and older age-classes, in ha;
x_{30} — area of stands in Ib (11—20 yrs old) and IIa (21—30 yrs old) age-classes, in ha;
x_{32} — degree of concentration of forest tracts;
x_{33} — length of boundaries of forest tracts, in hectometers;
x_{35} — feed and food from patches and from winter game feeding, in oat units;
x_{36} — fodder and food from patches, from summer feeding of game, in oat units;
x_{38} — area of forest-surrounded meadows and pastures, in ha;
x_{39} — area of forest with undergrowth, in ha.

Table 3 gives numerical values for explanatory variables in each of the units studied.

The characters mentioned were grouped into three alternative sets, each of which representing the group of factors constituting a combination of prevailing habitat conditions and game requirements.

The *A* set grouped following variables: x_7, x_9, x_{11}, x_{12}, x_{14}, x_{17}, x_{25}, x_{30}, x_{32}, x_{39}, the *B* set: x_8, x_{10}, x_{12}, x_{14}, x_{17}, x_{29}, x_{32}, x_{33}, x_{36}, x_{39}, while the *C* set: x_8, x_{10}, x_{25}, x_{26}, x_{28}, x_{29}, x_{30}, x_{35}, x_{36}, x_{38}.

Possibilities of arranging combinations of character sets are great. Apart from difficulties of technical nature, as adequate statistical processing of material or data collection, there are significant obstacles in the construction of models. One, which at best describes the actual statistical interrelationship between outcome and explanatory variables, will be optimal. The problem of forecasting of damage extent was solved with the aid of the method of multiple regression analysis. Relationships occurring between individual habitat characters were, therefore, presented in a form of the following linear function:

$$y_{(x)} = b_0 + b_1 x_1 + \ldots + b_p x_p + e; \qquad (1)$$

where:

y = outcome variable illustrating the extent of damage,

b_0 = constant extent of damage resulting from the failure of the model to include all causes affecting the occurrence of damage,

b_i = regression coefficient with i^{th} explanatory variable,

x_i = value of i^{th} explanatory variable,

e = random error.

It ought to be, however, stressed that the b_i coefficients "measures" the effect of the x_i variable exclusively with consideration to the effect of the remaining variables in the regression set considered. Removal or addition of even one explanatory variable may change, even significantly, values of b_i coefficients.

After supplementing the regression set considered (1) with squares of explanatory variables, we arrive at the parabolic regression model in the form of:

$$y_{(x)} = b_0 + \Sigma_1^p \ b_i x_i + \Sigma_1^p \ c_i x^2_i + e \qquad (2)$$

Coefficient of determination (R^2) provides the measure of regression model fitting to reality. Results of the examination of the significance of coefficients done with the aid of F-Snedecor and Student's t tests warrant that the function illustrates phenomenon with a desirable probability.

A great number of explanatory variables (20) considered in regression set is a drawback of a complete parabolic model. Hence suggestion that for practical purposes the model should include a lower number of variables, even at the cost of a poorer fitting. The parabolic model with the selection of characters from among 20 explanatory variables (presented in linear or square form) according to the maximal increase in the coefficient of determination meets such requirements. Above models, designed in numerous variants, were examined in three sets of characters (A, B, C) during three subsequent years and subjected to a general comparative analysis.

Computation was done with the aid of a regression computing programme written in ALGOL 1204 for the digital computer ODRA 1204 (Bartkowiakowa, 1978) in the Computation Centre, Wrocław University.

3. RESULTS

From the analysis of individual sets it resulted that a high value of coefficient of determination (R^2) occurred in the parabolic model for each of the years studied. This evidences that the model sufficiently well describes the average form of the relationship between the outcome and explanatory variables. Despite, however, high R^2 coefficient, the residual dispersion (se) was great in all cases, what should be explained by a high variation of outcome variables in the input data among individual forest districts.

Since studies were of procedural nature, the presentation of results of further analyses was based on only one of the sets, namely the *A* set. This set was considered to some extent as exemplary one. From the essential viewpoint it was considered that it represented both characters describing fundamental needs of game animals and fully corresponded with the recent economic situation prevailing in forests of Lower Silesia. Time factor did not play any role in these studies either. Subsequent years were seemingly rather replications of an experiment, than parts of studies disposed in time. That is why considerations were restricted to data from 1973, which characterized themselves, besides, with the highest values of R^2 coefficient.

In the set *A* the selection of characters for the forecasting of the total area of damage ($\hat{y}_1$) according to the regression model based on algorithm of selection of variables, was following:

— character No 9 — numbers of wild boars at the time of census;
— character No 17 — area of the fresh mixed coniferous forest.

Table 4
Model of regression equation based on the selection of variables. Estimation of the general values of compensation ($\hat{y}_2$). Total variation $se^2 = 144.1281$.

Number and form of variable x	Regression coefficient b value	Test t value
$(9)^2$	0.021716	5.23
14	-0.108723	4.78
$(25)^2$	0.0000026	4.17
30	0.238141	3.66
12	-0.064481	3.09
$(17)^2$	-0.000004	2.55
$(30)^2$	-0.000011	1.80

Significance level, $\alpha = 0.05$; $R^2 = 0.8013$; $F = 8.64$; $P < 0.001$.

Two explanatory variables are to be found here. Although the coefficient of determination amounted to only 0.4 it was nevertheless highly significant in a statistical respect ($\alpha = 0.007$). It seems that with more numerous research material one could obtain a higher R^2 value. In the case of the model with the character $\hat{y}_2$, the regression set contained no less than 7 explanatory variables. Their selection based on the criterion of a maximal increment of R^2 coefficient, enabled some kind of hierarchic arrangement according to their importance in the course of the determination of the outcome variable y_2.

A high value of R^2 coefficient and its obvious statistical significance occurred in combination with statistical significance of almost all coefficients of regression equation (Table 4). This arrangement of significance of characters selected by model corresponds with their order according to the parameter *t*.

Results obtained provide a rich material for broad concluding. Nevertheless, the character defining numbers of wild boars indicated the highest significance in all the sets examined.

Following values were obtained from the review of correlation coefficients calculated between outcome variables and wild boar numbers for 1973:

	y_1	y_2
r value for x_9	0.55	0.60
r value for x_{10}	0.65	0.69

with r significance $\geqslant 0.4$.

The sequence in the gradual selection of characters (with the addition of one variable at each step) in the analyzed regression model with the selection of variables was following: $(x_9)^2$, $(x_{17})^2$, x_{14}, $(x_{25})^2$, x_{12}, $(x_{30})^2$ Therefore: the first character, namely the number of wild boars (x_9), indicates the highest correlation with the outcome variable y_2.

The first character and the character describing the area share of the fresh mixed coniferous forest (x_{17}) are at most correlated with the y_2 outcome variable from among all possible pairs of explanatory characters;

Table 5
General form of regression equation according to the model with the selection of variables. Estimation of the value of compensation.
(Variant of character selection *A* from 1973).

No. of equation	Regression equation for Lower Silesian Plain	Determination coeff., R^2	Residual dispersion, *se*
1	$73.27+0.018960x^2_9$	.3703	117.0596
2	$87.99+0.022816x^2_9-0.000002x^2_{17}$	.4329	113.8301
3	$109.61-0.006005x_{14}+0.024355x^2_9-$ $-0.000003x^2_{17}$	.4822	111.6041
4	$153.77-0.040641x_{14}+0.022714x^2_9-$ $-0.000003x^2_{17}+0.000000816x^2_{25}$	.5738	104.0277
5	$70.17-0.070236x_{14}+0.061910x_{30}+$ $+0.021580x^2_9-0.00000413x^2_{17}+$ $+0.000000993x^2_{25}$	.6587	95.7876
6	$459.88-0.055726x_{12}-0.085568x_{14}+$ $+0.144275x_{30}+0.021626x^2_9-$ $-0.000002x^2_{17}+0.00000207x^2_{25}$	.7585	83.0521
7	$415.87-0.064481x_{12}-0.108723x_{14}+$ $+0.238141x_{30}+0.021716x^2_9-$ $-0.000004x^2_{17}+0.0000026x^2_{25}-0.000011x^2_{30}$	.8013	77.7980

First and second character, as well as that dealing with the area share of fresh coniferous forest (x_{14}) are at most correlated with the y_2 outcome variable from among all possible triplets of characters, etc.

While interpreting "significance" of each character one should acknowledge that the value of coefficients b assigned to them depends upon units in which variables are expressed and that their importance very strongly depends upon the regression set accepted.

As it was mentioned, the removal of explanatory variable, even one at least connected with the outcome variable, from a regression set may completely alter values of the remaining b coefficients. Series of regression equations were the final effect of calculations. Equation with 7 explanatory variables with the highest value of the coefficient of determination and lowest residual dispersion (Table 5) gives the smallest error in the prediction of damage value ($\hat{y}_2$) for an average forest district. Considering difficulties in the collection of data with so great number of variables it is permissible to reduce characters at least connected with the model at the cost of accuracy in forecasting the outcome variable. In the course of ex post elimination one finds, therefore, from among variables contained actually in regression set such, which would yield the smallest loss in R^2 coefficient, while maintaining the desired significance leval α_2. From the practical point of view the reduction in the number of characters will facilitate the application of the method. While analyzing the influence of individual explanatory variable upon the course of damage value, one finds that the explanatory variable of the areal proportion of fresh coniferous forest (x_{14}) has the strongest impact upon their decrease, while the size of the forest area of the district (x_{12}) and the areal proportion of the fresh mixed coniferous forest (x_{17}) do so to a lower degree. The remaining characters increase it.

Table 6
General form of regression equation according to model with the selection of variables estimation of the area of damage.
(Variant of character selection *A* from 1973).

No. of equation	Regression equation for Lower Silesian Plain	Determination coeff., R^2	Residual dispersion, *se*
1	$1.86+0.195395x_9$	.2984	10.1931
2	$3.45+0.265646x_9—0.001910x_{17}$	.3874	9.7602

Table 6 gives the general form of regression equations for the prediction of agricultural damage done by game ($\hat{y}_1$) in lowland forest districts of the Lower Silesia. The second of the two equations presented gives the lowest error of the estimate for an average forest district in the region analyzed. The negative value of regression coefficient in the 17th explanatory variable with a high numerical value of both coefficient and variable, evidences a serious influence exerted by the proportion of mixed fresh coinferous forest upon the reduction of the area damaged.

4. DISCUSSION

The presented method of the determination of statistical relationship between agricultural damage done by game and individual features of habitat constitutes from its assumption a model technique. It may, therefore, be used in the development of standards including features of the area described affecting the extent of damage in the form of definite statistical models. Apart from the possibility of the prediction of damage, this permits the interference into those features of habitat which are decisive for damage in the area analyzed. The preparation of input data for calculations is of prime importance. Already at the preliminary collection of data it was found that forest districts studied characterized themselves with a very high variation of values of outcome variables. In spite of the fact that high values of R^2 coefficients in the parabolic model (for y_1 the $R^2 = 0.90$; for y_2 $R^2 = 0.96$) gave the evidence that model described well the average form of relationship between given outcome variable and explanatory variables, nevertheless, the high in each case residual dispersion (*se*) revealed excessive differentiation of the material. This suggests the analysis of units in sets, in which these features would not reveal extremely different values. Development of conversion indices applicable for each study area (*e.g.* value of character per area unit) is an alternative solution. The departure from forest district to smaller units on the other hand seems to be unfavourable for practical purposes. It would cause difficulties in the collection of data, because most of them are available in documents in the forest district.

Subdivision of definite animal population or other character into parts (*e.g.* according to hunting reviers) could be burdened with serious errors. It seems also that a set accomodating more characters describing the status of an environment variable in time would provide better data for carrying out statistical analyses. In the present studies there were only seven of them, namely: numbers of animals during census and during the most severe damage, number of oat units during winter and summer, and acreage of winter grain. Obviously, there are no permanent characters sensu stricto. Alterations, however, are less significant (negligible changes in the area of a forest district, that of meadows, pastures, etc.) or occurring during a prolonged period of time, *e.g.* gradual shift from one into another age-class, changes in species composition of a stand, etc. This type of stability makes it possible to consider these features as "constant" and accept their values for the period of at least 10 years. In the case of radical alterations, which fundamentally change values of indices, it is necessary to redetermine relations between characters.

Further studies ought to proceed towards the development of optimal sets of diagnostic characters for definite natural and economic conditions. It should be recommended also to include elements connected with the structure and spatial organization of populations discussed in a set of characters. On the other hand statistical relationships ougth to be sought after with the use of a programme enabling the computation of regression from a higher number of variables that it was the case in the standard programme applied.

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METODA OKREŚLANIA RELACJI MIĘDZY ROZMIARAMI SZKÓD W UPRAWACH ROLNYCH, LICZEBNOŚCIĄ ZWIERZYNY GRUBEJ I WARUNKAMI ŚRODOWISKOWYMI

Streszczenie

Przedstawiono zastosowanie metody wielokrotnej analizy regresji dla skonstruowania modelu matematycznego określającego relacje pomiędzy populacjami jeleni i dzików (Tabela 2) i ich środowiskiem, a łowieckimi szkodami rolniczymi (Tabela 1). Materiał empiryczny zebrano w 23 nizinnych nadleśnictwach Okręgowego Zarządu Lasów Państwowych we Wrocławiu, dla trzech lat: 1973—1975. Charakterystykę każdego z badanych nadleśnictw opisano zbiorem 39 cech diagnostycznych, z czego przyjęto do dalszych analiz 21 cech (2 zmienne zależne i 19 zmiennych niezależnych — Tabela 3). Obejmują one zespół następujących informacji: powierzchnię szkód i wartość odszkodowań, liczebność jeleni i dzików, powierzchnię leśną nadleśnictwa, powierzchnię według typów siedliskowych lasu, powierzchnię według przewagi gatunkowej drzew, powierzchnię wg struktury wiekowej drzewostanów, stopień koncentracji komplektów leśnych, długość linii brzegowej kompleksów leśnych, karmę i żer z poletek, powierzchnię śródleśnych łąk i pastwisk, powierzchnię leśną z podszytem.

Badając zależności statystyczne występujące między elementami środowiska, a ich funkcją w postaci łowieckich szkód rolniczych stwierdzono, że najbardziej praktycznym w zastosowaniu jest paraboliczny model regresji, z redukcją zmiennych niezależnych determinujących zmienną zależną. Model ten w miarę dokładnie określa wartości przywidywanych szkód, co pozwala na różnego typu wyprzedzające działania gospodarcze. Analiza korelacji wielokrotnej między cechami wykazała, że największy wpływ na rozmiar szkód rolniczych mają w prezentowanym zbiorze następujące zmienne: (1) liczebność dzików, (2) udział powierzchniowy boru mieszanego świeżego, (3) udział powierzchniowy boru świeżego, (4) powierzchnia drzewostanów z przewagą sosny i modrzewia, (5) powierzchnia Ib (11 — 20 lat), IIa (21—30 lat) klasy wieku drzewostanów, oraz (6) powierzchnia leśna badanej jednostki (Tabela 4). Natomiast najsilniej skorelowana ze szkodami jest cecha określająca liczebność dzików (x_9) oraz cecha określająca udział powierzchniowy boru mieszanego świeżego (x_{17}). W wyniku badań otrzymano szereg równań regresji przydatnych do szacowania wartości (Tabela 5) i powierzchni (Tabela 6) rolniczych szkód łowieckich na nizinnych terenach Dolnego Śląska. W przypadku zmian warunków przyrodniczych lub gospodarczych, należy tą samą metodyką opracować odpowiednie reguły regresyjne, odpowiadające nowej rzeczywistości.