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Research in farm management technologies using the expert method

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Abstract. The task of the research was to state the most popular peculiarities of farm management technologies depending on the size of the herd in order to use the research results in calculations of greenhouse gas emissions. The research was performed applying the expert methods based on the farm management technologies as they are closely related to the size of the herd and the kind of the obtained farm manure. The expert method can be applied for research in farm management technologies of different animal species and groups, but in the present article only milk cow management technologies will be discussed as they produce the biggest amount of greenhouse gas emissions. The practice shows that on small farms the cows are tied, on medium farms – either tied or loose, but on large farms – only loose. On the farms where the cows are tied solid litter manure is obtained, but where the cows are handled loose – liquid manure is obtained. Besides, on the farms with a small herd the cows are pastured in summer and in this period manure spread in the pastures is produced. Stating the maximal size of the herd that is pastured and the length of the pasture period as well as the marginal size at which the transition from tied to loose handling takes place and additionally using the statistical data on the total number of cows in the country and the proportion of animals according to the size of the herd, it is possible to state from which proportion of milk cows solid litter is produced and from which – liquid manure. Therefore, the experts were given the task to name the marginal values of the above mentioned technology parameters based on the value intervals stated in advance. Thereupon that the experts had to state only one chosen value, it was not possible to apply the traditional expert evaluation methods and this method had to be adapted in accordance to the existing situation. The research results showed that in Latvia the critical size of the milk cow herd at which the transition from tied to loose handling takes place is 85 cows, the herds that are not larger than 90 cows are pastured but the pasture period lasts in average for 165 days.

Key words: farm management technologies, size of the herd, farm manure management, the expert method.

INTRODUCTION

Implementing the European economic zone program ‘National Climate Politics’ project ‘Development of a Methodology for Calculating GHG Emissions in the Agricultural Sector and Modelling Tool for Data Analyses, Integrating Climate

Change'– the task was set to state what kind of farm manure in Latvia is produced from the most popular farm animal and poultry species and their groups as well as to state the proportion of this manure. It was necessary for using the research results in calculations of greenhouse gas emissions caused by farm manure management.

Considering the data of the Guidelines for National Greenhouse Gas Inventories (2006 IPCC) and statistics as well as summarising and analysing the present experience of farm management specialists the most popular species and groups of animals used in agriculture and poultry as well as the kinds of farm manure produced by each of these groups were stated in Latvia. The obtained results are summarized in Table 1.

Table 1. Kinds of manure produced by the most popular farm animals in Latvia

Animal and poultry groups	Kinds of manure					
	Pasture manure	Solid manure	Liquid manure	Deep bedding	Poultry manure with litter	Poultry and fur animal manure without litter
Milk cows	x	x	x			
Milk cow calves and young stock	x	x				
Beef cattle, their calves and young stock	x	x				
Pigs		x	x			
Sheep	x			x		
Goats	x			x		
Horses	x	x				
Laying hens	x				x	x
Broilers					x	
Geese	x				x	
Ducks	x				x	
Turkeys	x				x	
Rabbits		x				
Fur animals						x
Deer	x					

Note: technology of farm manure used in the table is coordinated with 2006 IPCC.

In order to calculate the manure proportion obtained from the corresponding farm animals a new methodology was developed (Priekulis et al., 2015) based on using of the statistical data and the farm animal zootechnical and technological parameters. Some of the zootechnical and technological parameters necessary for the calculations are given in the scientific literature and the Regulations of the Cabinet of Ministers No. 834.

But additionally it is necessary to state the marginal sizes of the herd of every group of animals at which the transition from one kind of handling to another takes place and also the length of the animal pasture (airing) period. For this reason it was not possible to trace all farms (population) that are engaged in poultry and animal breeding in Latvia as in that case information on all the working force and financial resources would be necessary. Also, it was not possible to form representative and large enough sample farms as the farms engaged in poultry and animal breeding are unevenly distributed along the whole territory of Latvia. Nevertheless, this problem can be solved applying

the expert observation method and orientating on the research in animal and poultry breeding technologies depending on the size of the herd.

In order to show the possibilities of application of the expert observation method clearly as an example only one of the farm animal groups mentioned in Table 1 will be discussed, i.e., milk cows as they produce the largest amount of the greenhouse gas emissions (National Inventory Submissions, 2014).

MATERIALS AND METHODS

According to the scientific literature (Priekulis, 2000) and the practice it can be concluded that in Latvia on small farms (up to 50 milk cows) the animals are handled tied, on medium farms (50–200 cows) – tied or loose, but on large farms (more than 200 cows) – only loose. On farms with tied handling litter is used and solid manure is produced, but on loose handling farms litter is not used and liquid manure is produced. Besides, in summer cows from small and medium farms are usually pastured and therefore a part of manure is not collected as it stays in the pastures.

In turn, calves and young stock are usually handled loose either in individual or group enclosures (depending on the age). There litter is used that is periodically stocked up and the produced solid manure is taken to the manure storage if necessary. If milk cows are pastured, the young stock is pastured also. Therefore, it can be concluded that the obtained kind of manure is related to the kind of animal handling and the size of the herd on the farm.

One of the aims of the present research was to state the marginal value of the size of the herd at which the transition from one kind of handling to another takes place. Besides, the question about the maximal size of the herd that is pastured and the length of pasturing has also to be explained. Therefore, the experts were asked the following questions.

- What is the size of the herd (marginal value) at which the transition from tied to loose handling of cows takes place?
- What is the maximal size of the cow herd at which the cows are pastured (if there are pastures)?
- What is the average length of the pasturing period (number of days)?

The group of experts necessary for the research was completed according to the voluntary method including in it advisers from the Latvian Rural Advisory and Training Center, Latvian Milk Producer Association specialists as well as experienced animal breeding specialists and farm managers. The total number of experts was 18 people. It corresponds to the recommendations given in the scientific literature (Markovics, 2009) where 10–20 experts are recommended.

In order to get the individual opinion of the experts special enquiries or telephone enquiries were used. The task was to show the value interval in which, according to the opinion of the experts, the authentic value of the object lies.

Before the basic enquiry the pilot enquiry was performed. Its aim was to make the enquiry questions and the intervals of the researched values more precise and to state the understanding of the experts about the stated task.

Processing of the data obtained in the experiment was done in the following sequence:

- summarising of the ranging of the obtained results;
- selection of the data;
- determination of the extent of the expert agreement;
- obtaining of quantitative values from the ranged rows.

The enquiry results were ranged and summarised in a table the form of which is given in Table 2.

Table 2. Form of enquiry result ranging

Experts	Objects (n)					
(m)	x_1	x_2	…	x_i	…	x_n
m_1	r_1	r_{12}		r_{1i}		r_{1n}
m_2						
…						
m_j				r_{ji}		
…						
m_m	r_{m1}	r_{m2}		r_{mi}		r_{mn}
R_i						

Note: in the table with *n* the objects or their values are marked, with *m* – experts, with *r* – object ranging and with *R* – the resulting value of every object.

Still, it should be mentioned that all present expert evaluation methods are meant for the tasks to evaluate many objects, respectively, to state their ranged row. Problems occur if the team of experts has to evaluate only one value or take one decision as it is in the present research. In such case the research methods need to be adapted which in this case manifests as follows.

Every expert marks only the square of the object which he/she prefers. After that the ranged row is formed using the following approach.

- If the expert chooses gradation from one or the other end of the given row, this gradation is given the first range, the next gradation will be the second range, still the next – the third range etc
- If the expert chooses some gradation from the middle of the given row, the ranging can be as follows:
  – the chosen gradation gets the range 1;
  – the proximal gradations (to the left and right from the chosen) have equal range, but theoretically they occupy the 2nd and the 3rd range in the result of what every reduced range is calculated

$$r_{red} = \frac{2+3}{2} = 2.5;$$

  – further gradations to the left or right occupy the fourth and fifth range but the reduced range between the both is 3.5 etc.

If the expert chooses gradation from the middle of the row, the version is possible that the nearest to the chosen gradation will get the ranges 2; 3 etc. only in one direction,

for instance, to the right from the first range. Besides, gradations to the left will be ranged in the furthest end of the ranged row.

With such technique of adaptation all expert ranged rows for every square of the table can be obtained and it is possible to process the results mathematically by any of the traditional methods described in literature (Voronin, 1974; Hand et al, 2001; Dunham, 2003; Tan & Steinbach, 2006; Markovics, 2009).

After ranging of the results the data were selected. In practice the situations are possible when in the data array there is an 'extraneous' number present that does not fit in the total row of numbers. Therefore, the so called data selection is necessary that is done in all columns by turn.

The expert methods have a restriction that the degree of the expert agreement and the information obtained in the enquiry can be used in further calculations only in case if the degree of agreement is bigger than the threshold value. Therefore, big choices of techniques have been developed how to evaluate the degree of expert agreement, but the method of Kendall (Markovics, 2009) that is using the concordance coefficient has become most popular.

The concordance coefficient is calculated according to formula (1) or (2). If the expert evaluation ranges do not agree, formula (1) should be used.

$$W = \frac{\sum_{i=1}^{n}\left\{\sum_{j=1}^{m} r_{ji} - \frac{1}{2}m(n+1)\right\}^2}{\frac{1}{12}m^2\left(n^3 - n\right)}, \qquad (1)$$

where m – number of experts; n – number of objects; r – object range; i – object ordinal number; j – expert ordinal number.

If the expert evaluation ranges coincide, the concordance coefficient is calculated according to formula (2).

$$W = \frac{\sum_{i=1}^{n}\left\{\sum_{j=1}^{m} r_{ji} - \frac{1}{2}m(n+1)\right\}^2}{\frac{1}{12}m^2\left(n^3 - n\right) - m\sum_{j} T_j} \qquad (2)$$

In formula (2) the value T_j is calculated according to formula (3)

$$T_j = \frac{1}{12}\sum_{tj}\left(t_j^3 - t_j\right), \qquad (3)$$

where t_j – number of repeating ranges in *j-th* expert ranging.

The range of the concordance coefficient is from 0 to 1. If $W = 0$, there is no agreement among the ranging, if $W = 1$, there is complete agreement. To prove the statistic validity of the obtained result, the statistic hypothesis testing method with the Pearson coefficient χ^2 is applied. It is calculated according to formula (4):

$$\chi^2 apr = m(n-1)W \qquad (4)$$

From χ^2 tables χ^2_{tab} is found according to the freedom degree $v = n - 1$.

If $\chi^2_{tab} < \chi^2_{apr}$, then the hypothesis on expert evaluation agreement with the concordance coefficient is assumed with probability at least 0.95. It should be mentioned that by the Pearson criterion only the statistic validity of the concordance coefficient is tested. But this testing does not give information on whether the value of the concordance coefficient is high enough to judge about the agreement among the experts. Therefore, the question is open – what value of the coefficient W can be considered to be sufficient. It cannot be stated theoretically, but in practice it is assumed that the concordance coefficient is big enough if $W > 0.5$ (Markovics, 2009).

If the degree of agreement is larger than the threshold value, it is possible to obtain the quantitative values from the ranged rows. It is most easy to calculate the average arithmetic values for every column, but in case of a small number of data (such are all the data given by the experts) the average arithmetic value can give a big mistake. Therefore, a method, known in literature as Voronin method, is applied (Voronin, 1974). It is based on calculation of iterative mathematical expectation for small number cases. Mathematical expectation is calculated according to formula (5).

$$y_{ik} = \frac{\sum_{j=1}^{m} y_{ji} \exp\left[-\frac{\left(y_{ik-1} - y_{ji}\right)^2 (m-1)}{2\sum_{j=1}^{m}\left(y_{ik-1} - y_{ji}\right)^2}\right]}{\sum_{j=1}^{m} \exp\left[-\frac{\left(y_{ik-1} - y_{ji}\right)^2 (m-1)}{2\sum_{j=1}^{m}\left(y_{ik-1} - y_{ji}\right)^2}\right]} \quad (5)$$

where y_{ik} – mathematical expectation in *k-th* step; y_{ik-1} – mathematical expectation in the previous k-1 step; in the first step instead of y_{ik-1} the average arithmetic is put; y_{ji} – *i-th* object evaluation according to *j-th* expert opinion; m – number of experts.

To perform calculations using formula (5) special computer software 'MatLab' was developed in the programming media.

Considering that in the present research the experts have not to choose quantitative values but the intervals of these values, the task has to be adapted to the formal method. The values y_{ij} are obtained taking the average values from the intervals that every expert has evaluated with the first range. In the result a row of numbers is formed that is obtained replacing the first ranges in the table by the average values of the corresponding interval. Therefore, only one number is obtained – mathematical expectation of the searched marginal value that can be afterwards used for explanation of the researched problems.

RESULTS AND DISCUSSION

Ranging of the expert answers and the results of the expert agreement degree calculations related to the transition from tied handling of cows to loose handling are summarised in Table 3.

Table 3. Ranging of the expert answers and the results of the expert agreement degree calculations researching the question about the size of the herd at which the transition from tied handling of cows to loose handling takes place

Expert	Average size of herd (number of cows)				
serial No.	50–60	61–70	71–80	81–90	91–100
1.	3.5	2	**1**	3.5	5
2.	3.5	2	**1**	3.5	5
3.	4.5	3	**1**	2	4.5
4.	4.5	3	**1**	2	4.5
5.	4.5	3	**1**	2	4.5
6.	4.5	3	**1**	2	4.5
7.	5	4	3	**1**	2
8.	5	4	3	**1**	2
9.	5	4	3	**1**	2
10.	5	3.5	2	**1**	3.5
11.	5	3.5	2	**1**	3.5
12.	5	4	3	**1**	2
13.	5	4	3	**1**	2
14.	5	4	3	**1**	2
W	0.58				
Concordance coefficient W statistic validity	>0.99				

Table 3 shows that in this case the concordance coefficient $W = 0.58$, i.e., its value is higher than the sufficient value (W = 0.5) and also its statistic validity is high enough. So, the expert agreement degree is satisfactory and the value of the searched parameter can be calculated. The calculation results are shown in Table 4.

Table 4. Determination of the herd marginal size at which the transition from tied handling of cows to loose handling takes place

Expert serial No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Herd size interval, number of cows	75	75	75	75	75	75	85	85	85	85	85	85	85	85
Herd size critical size, number of cows	85													

Consequently, from Table 4 it can be concluded that the critical size of the herd at which the transition from tied handling of cows to loose handling takes place is 85 cows.

In turn, Table 5 shows the research results on the maximal size of the herd which is pastured

Table 5 shows that also in this case the degree of expert agreement is satisfactory (W > 0.5), so the searched value can be calculated. In turn, the calculation results show that the maximal size of the herd that is pastured is 90 cows.

Table 6 summarises the expert enquiry results on the length of the pasture period of cows.

Table 5. Ranging of the expert answers, the results of the expert agreement degree and mathematical expectation calculations determining the maximal size of the herd that is pastured

Expert	Size of herd, number of cows				
serial No.	< 50	51–80	81–100	101–120	121–150
1.	5	**1**	2	3	4
2.	5	**1**	2	3	4
3.	5	**1**	2	3	4
4.	5	**1**	2	3	4
5.	5	**1**	2	3	4
6.	5	1.5	**1**	1.5	4
7.	5	1.5	**1**	1.5	4
8.	5	1.5	**1**	1.5	4
9.	5	4	2	**1**	3
10.	5	4	2	**1**	3
11.	5	4	2	**1**	3
12.	5	4	2	**1**	3
13.	5	4	2	**1**	3
14.	5	4	2	**1**	3
W	0.76				
Concordance coefficient W statistic validity	>0.99				
Maximal size of herd, number of cows	90				

Table 6. Ranging of the expert answers, the results of the expert agreement degree and mathematical expectation calculations researching in the length of the cow pasture period

Expert	Length of the pasture period, number of days				
serial No.	145–150	151–160	161–170	171–180	181–185
1.	4	**1**	2	3	5
2.	4	**1**	2	3	5
3.	4	**1**	2	3	5
4.	4	**1**	2	3	5
5.	4	**1**	2	3	5
6.	4	**1**	2	3	5
7.	4	**1**	2	3	5
8.	4	**1**	2	3	5
9.	4	**1**	2	3	5
10.	4.5	1.5	**1**	1.5	4.5
11.	5	3	2	**1**	4
12.	5	3	2	**1**	4
13.	5	3	2	**1**	4
14.	5	3	2	**1**	4
15.	5	3	2	**1**	4
16.	5	3	2	**1**	4
W	0.78				
Concordance coefficient W statistic validity	>0.99				
Length of the pasture period, number of days	165				

Also for the answers summarised in Table 6 the degree of expert agreement is satisfactory, but the calculation results show that the average length of the pasture period is 165 days.

Applying the above described expert method similar research was performed also for the other farm animal groups included in Table 1 stating the length of the pasture (airing) period as well as performing research in the critical sizes of pig and laying hen herds at which transition from producing of one kind of manure to another takes place (for pigs – from solid manure to liquid manure, for laying hens – from solid manure to manure without litter).

These investigations show that application of the expert method opens wide possibilities for research in animal breeding technologies in the result of which new quantitative values are to be obtained. In the present case the change of farm animal handling depending on the size of the herd was taken as the basic principle of the research. But this method can be applied also in the research of another character where it is not possible to trace all farms (population) or form representative and quantitatively large enough sample groups.

Nevertheless, application of the expert method in the research in farm management systems can cause non-standard situations that are not described in scientific literature. For instance, in the present research the problem of determination of the expert agreement degree. It is based on comparison of ranged rows, but in the present research the experts chose only one value. Therefore, it was necessary to formalize the obtained results in accordance to the calculation methods and to adapt the initial data to calculate the mathematical expectation applying the Voronin method.

CONCLUSIONS

In order to state the peculiarities of farm animal handling technologies for the most popular animal species and groups in Latvia it is not possible to trace all farms that are engaged in poultry or animal breeding. Also, it is not possible to form representative sample farms as the farms of the corresponding animals are unevenly scattered along the whole territory of Latvia. Still, this problem can be solved applying the expert evaluation method and basing on the changes of farm animal and poultry handling technologies depending on the size of the herd.

Applying the expert evaluation method it has been stated that the size of the milk cow herd at which the transition from tied handling to loose handling takes place as well as from producing of solid manure to liquid manure is 85 cows. Besides, the animals are pastured and manure left in pastures is obtained if the size of the herd does not exceed 90 cows, but the average length of the pasturing period is 165 days.

As the experts participating in the research had to choose only one interval of values that best suits the given question, it was not possible to apply the traditional expert evaluation methods. Therefore, it was necessary to adapt the ranging determining the expert agreement degree as well as formalising the number rows calculating the mathematical expectations.

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