The analytic hierarchy process in decision-making for caprine health programmes

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Summary
The purpose of this study was to apply the analytic hierarchy process (AHP) to assist decision-making when planning animal health programmes, by assigning priorities to issues of concern to producers in Chile's main goat production region. This process allows a multi-criteria approach to problems, by analysing and ranking them in a hierarchical structure. Industry experts have highlighted the following animal health and disease control criteria: acceptance by breeders of disease control measures; impact of specific diseases on regional animal trade; the cost and efficacy of control measures; a decrease in flock production; and the impact of caprine diseases on human public health. Using these criteria in the AHP, the study found that the most important impacts were on human public health and on the animal trade. The disease priorities were tuberculosis, brucellosis and echinococcosis/hydatidosis, due mainly to their zoonotic impact. The analytic hierarchy process proved useful when several criteria were involved in public health issues.

Keywords
AHP – Analytic hierarchy process – Animal health programmes – Brucellosis – Caprines – Chile – Decision-making – Echinococcosis – Hydatidosis – Tuberculosis.

Introduction

Measures to control livestock diseases require material, human and operational resources, such as medication, equipment, specialised personnel, etc. Controlling such diseases, therefore, can become incredibly expensive and require vast resources, which are frequently limited in the countries in which they are most needed.

This situation often forces producers to prioritise the various animal health problems faced. Priorities in animal health can be defined as the selection of those sanitary problems, programmes or activities that must be addressed first, in order to improve an animal health system.

Prioritising animal health matters is always difficult because, in general, it must be done with scarce information over a short period of time. This reality forces regional or national health services to assign budgets using previously gathered data, so that they can direct current resources to those areas with traditionally greater needs.

This task is made harder when there are a variety of criteria, all of which must be considered when making decisions on animal health problems. Such criteria include public health, economic, social and environmental issues. This complexity prompts us to discard the tools used in traditional decision-making models, which were based mainly on a single criterion, such as cost-benefit analysis.

The analytic hierarchy process (AHP) represents an appealing methodological option because it is able to deal with decision-making when many criteria are involved, requires less quantitative information and, with the availability of Expert Choice software, facilitates group work (2).

The objective of this investigation was to examine the potential of the multi-criteria decision-making method when making public decisions on animal disease control. In this study, AHP was applied to rank various animal health problems among livestock in Chile's Coquimbo region.

Materials and methods

The analytic hierarchy process

The methodology used is based upon the application of the AHP, developed by Thomas Saaty at the end of the 1970s (7, 8) and catalogued among the discrete multi-criteria models for decision-making.

The basic feature of the AHP is the assignment of weight vectors $W = [w_1, w_2,..., w_n]$ to the criteria of a certain multi-criteria decision problem. For this, it is necessary to compare each criterion i with criterion j, assigning to each paired comparison certain values a_{ij}, according to the following Saaty rating scale (8):

A_{ij} value   When criterion i, compared to j, is...

1   Equally important

3   Slightly important

5   Much more important

7   Very much more important

9   Absolutely more important

This information can be collected in an ordered squared matrix, which is known as the binary comparison matrix $A[a_{ij}]$ (1). The dominant vector w is then calculated. An important consideration, in terms of the *quality of the final decision*, is related to a judgement's consistency, as validated by an expert. The measurement of the judgement's consistency is obtained by calculating the consistency ratio (CR). A matrix is consistent if its elements observe the assumption of transitivity and proportionality of the preferences. A reasonable level of consistency in the paired comparisons is a CR of 0.1 or less (3).

Software from Expert Choice Inc., based upon the AHP method, was used to simplify the calculation procedure.

Methodology for applying the analytic hierarchy process

The application of AHP requires several stages:

– . defining the problem

– structuring the problem

– evaluation

– incorporating uncertainty into the decision-making process.

Problem definition

In this stage the general objective of the decision must be clearly defined, together with the actors involved and the means necessary to achieve it.

1. The general objective: to prioritise the animal health problems of goat production in a certain region in order to focus a campaign more effectively.

2. Definition of actors: the participants involved in the decision-making process. They must be carefully selected, because the faithfulness of the model depends on them. In this case, the decision centre consisted of a group of eight experts, as defined below, with the following attributes:

– an expert must possess experience and academic excellence in areas related to the topic of the decision problem; in this case, epidemiology, veterinary economics, animal health programme planning, commercialisation of animal products, caprine production, caprine livestock infectious and parasitic diseases

– an expert must have a public, private or academic position which entails knowledge and management of updated information on the production, health and/or commercialisation of caprine livestock.

To facilitate group work carried out by experts, Garuti and Spencer (4) recommend involving no more than ten people.

Structuring the problem

The problem must be arranged into a hierarchical structure by dividing it into smaller parts, thus providing less complex, easier-to-manage sub-problems. Most people intuitively deal with their problems in this way by:
– establishing the objectives
– defining the criteria
– determining alternatives to be compared
– defining the hierarchical structure.

Evaluation

The evaluation step of the AHP is divided into the following three sub-stages:
– evaluating alternatives
– evaluating the criteria
– prioritising the alternatives.

The first two sub-stages are independent and can be carried out in any order.

Incorporating uncertainty into the decision-making process

To make the decision more reliable, a level of variation must be set for the relative weight of strategic criteria

which will support the decision without changing the proposed alternative. To achieve this, a sensitivity analysis is performed in which different scenarios are considered, determining the cut-off points to the weight of each criterion.

The application of the AHP method to find solutions for caprine animal health problems in the Coquimbo region used the following steps, as shown in Figure 1.

Results and discussion

Model structure

Guidance objective

The high priority placed on caprine health in the Coquimbo region was used as an objective guide to assign resources more effectively when developing health control programmes or projects.

Prioritisation criteria

These criteria were based on the opinions of the experts, who took into consideration the information provided by field veterinarians with access to caprine herds in the region. The following criteria were considered for prioritisation:
- acceptability
- public health
- production
- efficacy
- cost
- trade.

Acceptability

This criterion involves the producers' knowledge and acceptance of the measures involved in preventing diseases in their herds. It should be noted that one disease would become more important than another if its control measures were more likely to be accepted by the caprine livestock producers of the Coquimbo region.
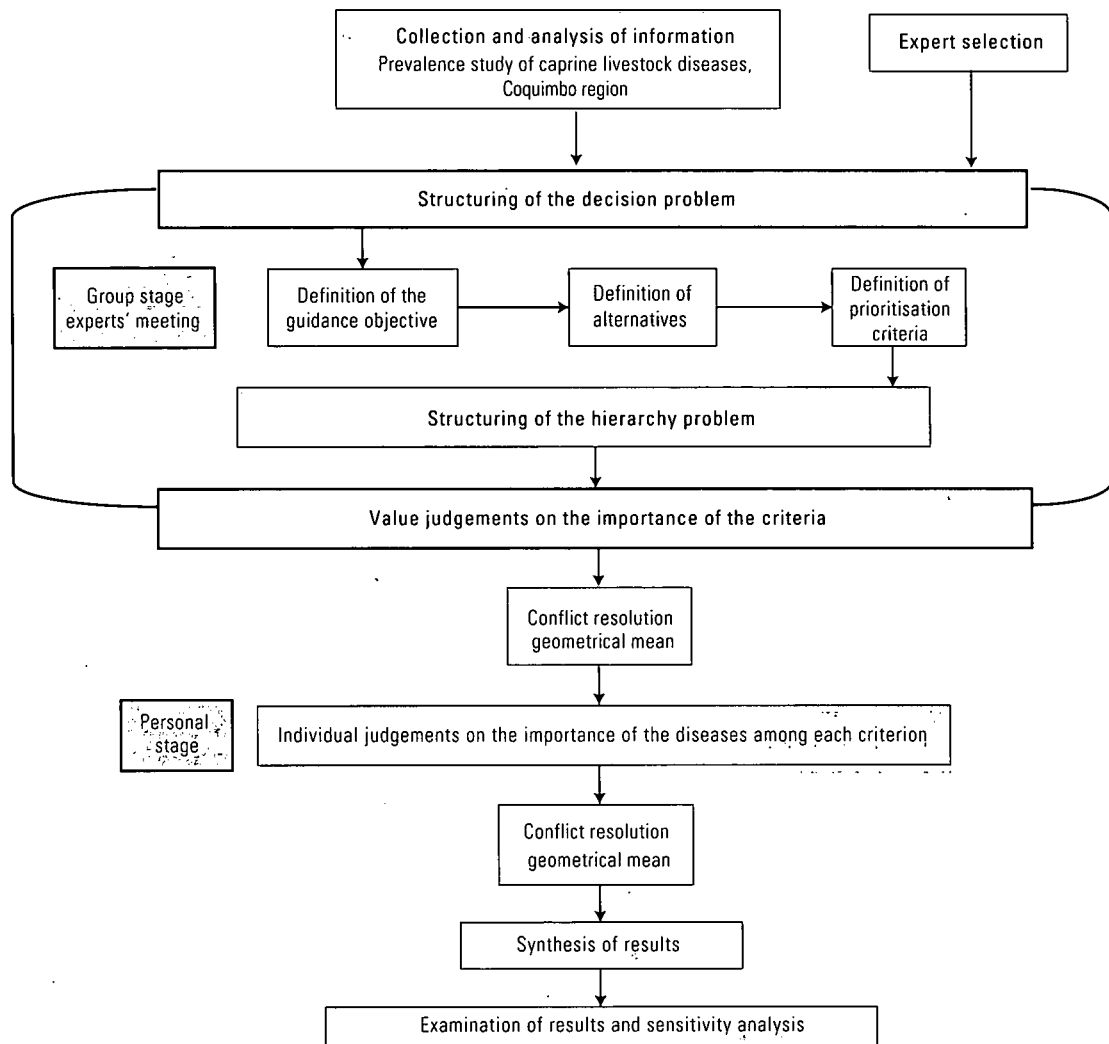

Fig. 1
Sequence to determine priorities (5)

Public health

This criterion was defined as the impact of a caprine disease on the health of the general human population in the Coquimbo region.

Production

This criterion corresponds to the estimated loss of production caused by the disease and its hampering effects on the ability to improve productivity.

Efficacy

This refers to the probability of achieving prevention or control of a known caprine disease in the Coquimbo region, irrespective of previous criteria. In other words, this criterion is connected to the effectiveness of the control measures available to confront a specific disease threat.

Cost

This refers to the economic cost of carrying out disease prevention or control projects. One disease is considered to be more important than another if the cost of implementing the possible prevention or control measures is less.

Trade

This criterion represents the impact of a disease on the formal trade of products, sub-products and derivatives of caprine livestock in the Coquimbo region.

When analysing the decision problem, the selected criteria are classified into two types or groups:

— impact criteria, which, in this case, refer to the impact of diseases on various fields, such as production, trade and public health

— control criteria, which are related to the feasibility of implementing control measures, taking into account the cost, efficacy and acceptability of these measures.
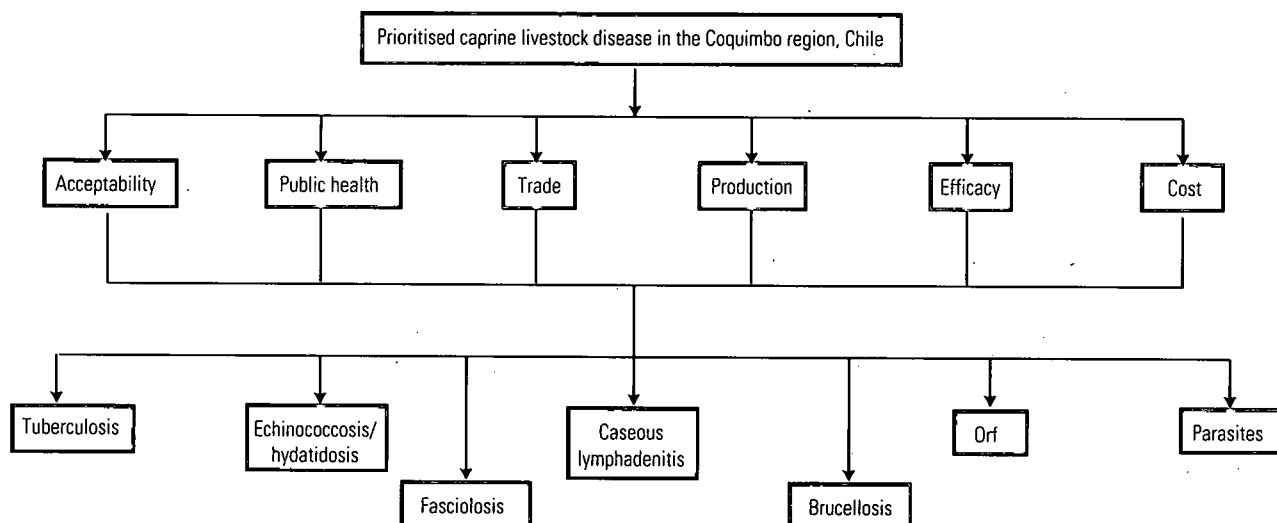
Diseases

There were seven diseases identified by the experts, which affect or could affect caprine livestock in the Coquimbo region. These were considered and evaluated according to their importance in the areas of zoonoses, loss of productivity, occurrence, and/or risk of introduction into the area. The alternatives selected were:

— tuberculosis (Mycobacterium bovis)

— echinococcosis/hydatidosis (Echinococcus granulosus)

— caseous lymphadenitis (Corynebacterium pseudotuberculosis)

— fasciolosis (Fasciola hepatica)

— orf/contagious ecthyma (Poxviridae)

— parasites (gastro-intestinal and pulmonary)

— brucellosis (Brucella melitensis).

The last has not been detected in Chile for several years, but its introduction would present a significant problem for both animal and public health.

Foot and mouth disease was not considered because Chile was declared free of the disease in 1981 and a national surveillance programme is in place, which takes prevalence over any regional initiative. Chagas disease was omitted because it is controlled by a public health institution and was therefore not considered to be within the sphere of animal health decision-making. Mastitis, diarrhoea and respiratory complexes were also put to one side, being

Fig. 2
Hierarchic structure of the problem

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considered the responsibility of the private sector rather than the public sector.

This work includes both the decision criteria and the diseases to be prioritised, as determined by the industry experts.

Hierarchic structure

The hierarchic structure of the decision-making process has three levels, as shown in Figure 2. The first level contains the guidance objective; the second level includes the prioritisation criteria and the third level comprises the diseases.

Evaluating the problem

The relative importance of the criteria

Industry experts submitted their value judgements on the importance of the prioritisation criteria in regard to the guidance objective. In those comparisons without consensus, a geometric mean was applied to the individually assigned value. A distributive synthesis was used to analyse the relative weights and priorities in the Expert Choice programme.

As shown in Table I, the public health criterion was valued most highly among the criteria, within a range of 2 – 4 on the Saaty fundamental scale, while the cost criterion was evaluated as the least important when compared to the other criteria. The majority of the comparisons among the criteria which ranked their importance with respect to the guidance objective did not reach values greater than 4, except for the cost and trade comparison, with a value equal to 5.

For the matrix represented in Table I, the characteristic vector *w* was given by the values shown in Figure 3. The public health criterion obtained a relative weight of 0.369, followed by the trade and acceptability criteria, with weights of 0.212 and 0.153, respectively.

Table I

Consensus on the values for the pair criteria comparison in relation to the guidance objective

The values correspond to the relative importance awarded the criteria, according to the Saaty fundamental scale, when comparing the criteria in the first column with those of the first row. The brackets indicate inverse importance

Criterion	Public health	Production	Efficacy	Cost	Trade
Acceptability	[4]	3	3	2	[3]
Public health		3	2	4	4
Production			[3]	3	1
Efficacy				2	[3]
Cost					[5]
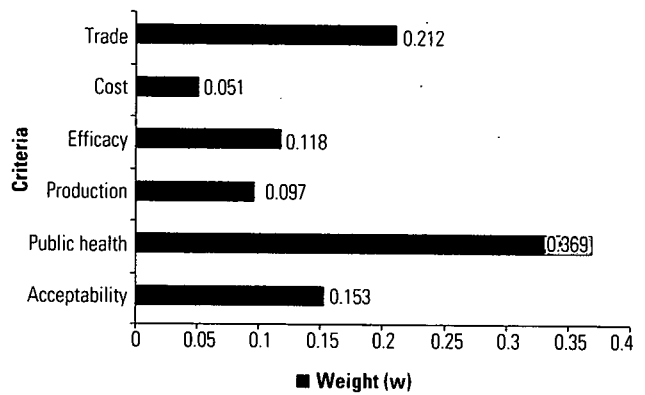
Fig. 3
Prioritising criteria to achieve the objective

According to these results, the impact that caprine diseases could have on livestock and on the health of the general public was the most important criterion in prioritising the diseases. This would lead to a different perspective on the animal health issue, with a notable raised valuation for zoonoses over other diseases. An ethical–moral factor comes into play when granting such importance to this criterion.

In general, the *impact criteria*, over all, possess a relative weight which duplicates the feasibility criteria group. After consulting experts from both the public and academic sectors, it was found that the impact of the diseases overrides the economic feasibility of carrying out control measures and their efficiency. Perhaps, if the investigation had included input from the private sector, other criteria would have been assigned greater relative importance, such as the impact of the disease on the production system.

On the other hand, the acceptability criterion was ranked third in priority. Experts have found, by virtue of field experience, that many control or preventive measures fail because there is little acceptance by producers. Caprine production in the Coquimbo region is run mainly by farming families, using an extensive, traditional form of management, with low intervention levels. Low levels of schooling and formal education among goat owners in the area possibly exacerbate this situation. In addition, within a portion of owners, caprine production constitutes only a part of the family's economic activities and, therefore, not enough time or resources are dedicated to the control measures. Finally, the diseases described are not always recognised as problems. These, among other reasons, could explain why new disease control measures do not gain a high level of acceptability in the region.

The cost criterion was ranked last and least important within these results. This could be explained by the fact that this criterion was proposed only as a comparison

point, favouring the prioritisation of diseases which required less expensive control strategies, and not as an actual overall budgetary constraint.

Final priority

As shown in Figure 4, the final disease characteristic vector indicates that tuberculosis, brucellosis and echinococcosis/hydatidosis were ranked as the first three priorities, with values of 0.245, 0.210 and 0.189, respectively. They were followed by internal parasites (0.116) and fasciolosis (0.098) and, finally, by caseous lymphadenitis (0.078) and orf (0.067). The final CR reached 0.1, which is considered reasonable (3).

These final results indicated the existence of three priorities or disease groups. The first group/priority corresponded, in order of importance, to tuberculosis, brucellosis and echinococcosis/hydatidosis, which, in all, made up 64% of the total weighting. The second group was comprised of internal parasites and fasciolosis, while caseous lymphadenitis and orf were last on the list of priorities.

This priority structure can be explained by the importance given by the experts to the public health criterion. Consequently, diseases that more directly compromised public health, such as zoonoses, were given higher priority.

However, a different treatment could have been considered for zoonoses; separating them from other diseases for prioritisation. On the other hand, their prevalence and the risk of their appearance in the analysed territory should be taken into account, to avoid possibly overestimating their significance. Zoonoses, which can be classified as very important or dangerous for human health, can have such a low prevalence or risk of occurrence that their relative importance may be seen as less than that of another disease.
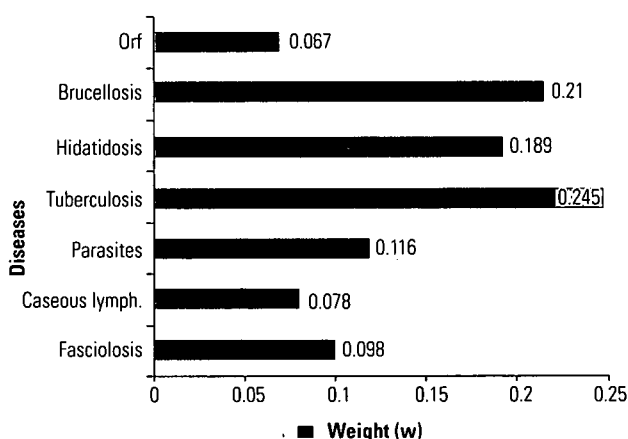
Advantages of the analytic hierarchy process when solving animal disease priority problems

The authors would like to highlight two positive features of the AHP method for solving subjective problems, in comparison with a one-criterion method, such as cost-benefit analysis. First, when there is more than one criterion to choose from, it soon becomes evident that criteria linked with public health always appear when dealing with animal health issues. Furthermore, in this type of study, environmental criteria are appearing more and more frequently when these decisions need to be made. Thus, incoming diseases, which may threaten certain protected species, generate new criteria that must be considered when prioritising which diseases to control. Closely linked to this is the qualitative issue, in that advantages and disadvantages associated with a decision cannot always be converted into a common unit of measurement, e.g. weight, which is demanded by cost-benefit analysis. A good example of this is public health. It is true that, by using certain existing methodologies, we may approximate the monetary value of a criterion. Nevertheless, it is also true that this criterion involves important ethical issues, as well as lesser criteria linked to the costs and precision of any potential solution, which makes a quantitative assessment impractical for these types of problems.

On the contrary, quantitative information about the possible results reached by each alternative in each considered criterion is not essential when applying the AHP method, since it is based on value judgements, made by experts at the decision centre (or the heart of the decision), about the relative importance of one criterion in relation to another. This approach adds an element of realism to the decision-making process, when dealing with animal health issues.

Another advantage in using this method, especially when compared to other multi-criteria methods, is that it simplifies the difficult process of managing decisions in complex scenarios. The technique of organising criteria into a hierarchy, proposed by Saaty, in essence reduces a problem's complexity by itemising and analysing each of its parts. This method also allows an opportunity to assess the consistency level provided by the experts when setting up their preferences. Besides being easy to use, the AHP generates a synthesis and provides a sensitivity analysis.

However, the use of this methodology also has some drawbacks:

– there are significant costs involved in procuring qualified labour and related investigations

– there is often a delay in implementing the required actions, especially in public institutions, which are often very rigid.

Fig. 4
Ranking the diseases in order of priority

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Finally, it is important to emphasise, as pointed out by Martínez (6), that the use of the AHP does not guarantee an optimal decision. It generates a decision based on the detailed analysis of a problem and the synthesis of relevant information, based on the knowledge, experiences and preferences of the various participants involved in the decision-making process.

Sensitivity analysis

As previously stated, a sensitivity analysis is a useful tool to determine how much importance can be assigned to the various criteria, without significant variation in the final ranking of priorities. Table II illustrates the values of critical points which must be reached by each criterion to produce a change in the priorities of the most outstanding alternatives (in this case, tuberculosis, brucellosis and echinococcosis/hydatidosis). For example, the public health criterion must reduce its relative importance (weighting) to 0.045 to produce a change in the prioritisation of the diseases to be considered for intervention.

Table II
Sensitivity analysis of critical points

Criterion	Weight (w)	Critical point (p$_i$)	Variation (%)
Public health	0.309	0.045	85
Acceptability	0.153	0.280	83
Efficacy	0.118	0.338	186
Cost	0.051	0.214	320

Conclusions

The analytic hierarchy process is useful for making decisions on animal health issues, where several criteria must be considered and it becomes difficult to convert them into a common unit of measurement (e.g. monetary units). This method adapts well to public health issues as it does not demand quantification of the variables, but rather places values on judgements by which the decision can be made.

In the analytic hierarchy process, participation of individuals or groups in making decisions (networks) is key and, since communication between field experts is always available, this ensures a reliable method of measuring criteria for maximum benefit.

After comparing the relative importance of the criteria for prioritisation, the experts assigned greater impacts to diseases that affect human health. Resources were eventually assigned to caprine animal health programmes that targeted zoonoses in the Coquimbo region, such as tuberculosis, brucellosis and echinococcosis/hydatidosis.

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L'analyse multicritères hiérarchique : une aide à la décision pour les programmes sanitaires caprins

M. Maino, P. Pérez, P. Oviedo, G. Sotomayor & P. Abalos

Résumé
Dans la présente étude, la méthode d'analyse multicritères hiérarchique (AHP) a été utilisée pour hiérarchiser par priorités les problèmes rencontrés par les éleveurs de chèvres dans la principale région de production caprine du Chili, en vue d'étayer les décisions relatives à la planification des programmes de santé animale. La méthode AHP permet de s'attaquer aux problèmes en abordant plusieurs critères à la fois, qui sont analysés et classés par priorités. Les experts de la filière ont mis en avant les critères suivants en matière de santé animale et de lutte contre les maladies animales : acceptation par les éleveurs des mesures

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de lutte ; conséquences de certaines maladies spécifiques sur les échanges régionaux ; coût et efficacité des mesures de lutte ; chute de la production des troupeaux ; conséquences des maladies caprines pour la santé publique. L'analyse AHP a révélé que les effets les plus importants étaient ceux qui affectaient la santé publique et les échanges d'animaux domestiques. Les maladies prioritaires (principalement du fait de leur caractère zoonotique) étaient la tuberculose, la brucellose et l'échinococcose/hydatidose. L'AHP s'avère fort utile lorsqu'il s'agit de prendre en compte une multiplicité de paramètres susceptibles de jouer un rôle dans les problématiques de santé publique.

Mots-clés
Analyse multicritères hiérarchique (AHP) – Brucellose – Caprin – Chili – Échinococcose – Hydatidose – Prise de décision – Programmes de santé animale – Tuberculose.
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El proceso de jerarquía analítica en la adopción de decisiones sobre programas de sanidad caprina

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Resumen
Los autores describen un estudio destinado a aplicar el proceso de jerarquía analítica (PJA) como instrumento auxiliar en la adopción de decisiones sobre la preparación de programas de sanidad animal, definiendo a tal efecto un orden de prioridades entre los temas que preocupan a los ganaderos de la principal región de producción caprina de Chile. Este proceso permite abordar problemas analizándolos y jerarquizándolos conforme a múltiples criterios. En materia de sanidad y enfermedades animales, los expertos del sector han señalado los siguientes criterios básicos: aceptación por los productores de las medidas de lucha zoosanitaria; influencia de determinadas enfermedades en el comercio regional de animales; costo y eficacia de las medidas de lucha; caída de la producción de los rebaños; y consecuencias de las enfermedades caprinas para la salud pública humana. Utilizando estos criterios en el PJA, los autores del estudio descubrieron que la salud pública y el comercio de animales eran los ámbitos en que las consecuencias eran más notorias. Las enfermedades prioritarias eran la tuberculosis, la brucelosis y la equinococosis/hidatidosis, sobre todo por sus efectos zoonóticos. Se comprobó que el proceso de jerarquía analítica resulta útil al examinar cuestiones de salud pública en las que entran en juego diversos criterios.

Palabras clave
Adopción de decisiones – Brucelosis – Caprinos – Chile – Equinococosis – Hidatidosis – PJA – Proceso de jerarquía analítica – Programas de sanidad animal – Tuberculosis.
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References

1. Ballestero E. & Romero C. (1998). – Multiple criteria decision making and its applications to economic problems. Kluwer Academic Publishers, the Netherlands, 1–10.

2. Fernández F., Caballero R. & Romero C. (2004). – La aventura de decidir: una aproximación científica mediante casos reales. Red temática de decisiones multicriterio. Universidad de Málaga, Spain.

3. García J., Salvador A., Noriega S., Díaz J. & De la Riva J. (2006). – Aplicación del proceso de jerarquía analítica en la selección de tecnología agrícola. *Agron. Costarric.*, **30** (1), 107–114.

4. Garuti C. & Spencer I. (1993). – Metodologías recientes para la evaluación de impacto ambiental de proyectos: análisis multicriterio y AHP. Fulcrum Ingeniería Ltda, Santiago, Chile.

5. Huizingh K.E. & Vrolijk H.C.J. (1995). – Decision support for information systems management: applying analytic hierarchy process. Research report No. 95325. Graduate School/Research Institute, Systems, Organisations and Management (SOM), University of Groningen, the Netherlands.

6. Martínez E. (2007). – Aplicación del proceso jerárquico de análisis en la selección de la localización de una PYME. *Anuario jurídico y económico escurialense*, **XL**, 523–542.

7. Saaty T.L. (1994). – Fundamentals of decision making and priority theory with the analytic hierarchy process. The analytic hierarchy process series, Vol. 6. RWS publications, Pittsburgh, Pennsylvania.

8. Saaty T.L. (1996). – The analytic hierarchy process: planning, priority setting, resource allocation. The analytic hierarchy process series, Vol. 1. RWS publications. Pittsburgh, Pennsylvania.