Evaluation of health and productivity of small ruminants in Africa: the example of Senegal
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Summary: The authors describe a system of investigation introduced into Senegal in 1983; their purpose is to extend knowledge about the farming of small ruminants and the epidemiological relevance of such farming.

The investigations are conducted in the traditional livestock sector by using a multidisciplinary approach. The precision and reliability of the information depend on the recording and processing of data on individual animals.

The system of investigation has a modular structure organised around a central module for demographic surveys. The peripheral modules correspond to specific activities: clinical surveillance, recording changes in body state, laboratory tests and a study of animal husbandry conditions and practices.

The authors distinguish four levels of analysis depending on the origin of variables under consideration: a single module (level 1), the demographic module plus the peripheral module (level 2), the demographic module plus two or more peripheral modules (level 3) and one or more modules derived from experimental modification of certain features of the husbandry system (level 4).

The constraints and limitations of the procedure are discussed.

KEYWORDS: Africa - Data banks - Data collection - Epidemiology - Goats - Senegal - Sheep - Traditional husbandry - Veterinary services.

INTRODUCTION

In intertropical Africa, the rearing of ruminants is mainly in the hands of traditional farmers.

Little is known of this traditional animal husbandry, including its constraints and performance, because of inadequate means for conducting a thorough investigation in the “uncontrolled” sector. Most often, researchers have access only to imprecise and unreliable information gained from limited surveys.

While precision is not always indispensable, the lack of precision is nevertheless a constraining factor in certain studies. The value of epidemiological studies, in particular, is enhanced by a precise description of the population in which a disease occurs: a demographic basis and past history are necessary. Because the demographic

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basis in Africa derives from incomplete surveys and extrapolations, it tends to be approximate and undetailed; a case history, therefore, is usually available only for very recent events.

Several research teams have proposed alternatives, in the form of individual surveillance operations conducted over several years (10, 12), for studying the traditional farming sector. In 1983, inspired by a procedure developed in northern Côte d'Ivoire by the Savanna Institute and in collaboration with the Institute for Animal Husbandry and Veterinary Medicine in Tropical Countries (IEMVT), the Senegal Agricultural Research Institute (ISRA) started a programme for individual surveillance of sheep and goats under different types of husbandry in Senegal (from the Sahelian to the Sudano-Guinean zones). The “Pathology and Productivity of Small Ruminants in Senegal” programme (PPR programme) is multidisciplinary, combining animal husbandry, pathology and the micro-economy.

The originality of the adopted system is its modular structure, which makes it possible to attach peripheral modules, each devoted to a special topic, to a central module for demographic surveys. The various modules can be readily connected to bring together data on a given animal or group of animals.

This relational aspect has numerous advantages in planning the management and analysis of information. In particular, a research worker can gain access not only to the conclusions of his colleagues but also to their crude data, which he may then validate, supplement and use to interpret his own observations. The different disciplines are not simply juxtaposed around a common object; they overlap so that gathered information can be exchanged, thereby creating the conditions for real interdisciplinary action. Several levels of analysis are obtainable, according to whether the observations of just one module are being dealt with (which is always possible) or whether the observations of numerous modules are combined.

The theoretical and practical aspects of this system of individual surveillance have been published elsewhere (3, 5, 7); the following account deals with the point of view of the epidemiologist. The first part briefly describes the principles of collecting and processing data obtained from the surveillance team; details are then given of those modules of special interest to epidemiologists.

**PRINCIPLES AND CONSTRAINTS**

**Principles**

To obtain precise data for the traditional sector comparable to data obtained at research stations, it is necessary to keep records for individual animals. The value of this practice has been amply demonstrated.

Owing both to the complexity of the environment of this sector and to the diversity of information about it, a multidisciplinary investigation is essential. Only by this approach can the various factors which affect performance be identified and the collected information structured for recording and effective use.

Precise knowledge of the status and changes in the populations of the domestic animals under study is a primary concern of research workers operating in an
"uncontrolled" environment; it is only logical, therefore, to centre the management of collected information on demographic surveying. This central module deals specifically with population data, recording any alterations in the structure and dynamics of a population; it is the nucleus to which all disciplines and researchers, while maintaining their specific and independent modules, are linked (Fig. 1). By ensuring the general cohesion of the system, this choice has proved particularly operational in practice.

**FIG. 1**

*Modules of the PPR programme which can assist epidemiology*

As regards data processing, four levels of analysis can be distinguished according to the variables used and the modules involved (Fig. 2).

- Level 1: examination of the variables arising in a single module;
- Level 2: simultaneous examination of variables arising from the demographic base module and one of the peripheral modules;
- Level 3: simultaneous examination of variables arising from the demographic base module and two or more peripheral modules;
- Level 4: simultaneous examination of variables arising from one or more modules after experimental modification of certain features of the husbandry system.

**Constraints**

The functioning of a system of individual surveillance imposes a certain number of constraints upon the environment of traditional husbandry.
Identification of the objects under examination

Identification of animals and flocks or herds must be at once simple and reliable.

Permanent identification of individuals is done by ear tags, attached soon after birth or when an animal enters the flock or herd. It is checked systematically at each event which occurs during the life of the animal and is linked to other information (number of the dam, sex, date of birth, flock/herd) in such a way as to avoid confusion between individuals. The rare instances of loss of ear tag are easily managed. Young animals not yet tagged are recorded and identified by reference to their dam.

The basic unit for the aggregation of animals is the so-called “concessionary” herd, for which the head of a family is responsible. (“Concession” applies to the right to use land owned by a community). Concessionary flocks or herds provide the measure by which changes in the animal population (gains and losses) are recorded.

For aggregation of data, larger units of settlement (hamlet, village, rural community, region) are easily defined to meet the specific needs of each analysis.

Continuous surveillance over a long period

The quality of data must be assured by regular and frequent (fortnightly) visits. The observer has to confirm in person all the events which have taken place, or at least to identify any change in herd structure since the previous visit. The events (birth, death, sale, illness, etc.) having been identified, the observer obtains exact information on each circumstance, which must be recent if it is to be reported accurately by the person in charge of the animals.
Many estimates are calculated from annual figures. Most are subject to seasonal and year-to-year variations and therefore have to be considered over several years. Moreover, estimates related to production are not usually obtainable without an adequate backlog. This requires a surveillance period of several years, at least five in the case of small ruminants, and includes at least one year for implementation and settling down.

**Major animal populations**

Since performance under traditional husbandry varies widely, demographic surveillance of the type mentioned above needs to be applied to populations of at least a thousand animals of the same species in a particular zone if statistically adequate precision is to be obtained for the parameters examined. In practice, data-processing techniques and the methods used in the field can cope with even larger populations.

It is clear that logistic difficulties become more serious as both the number of surveillance sites and the number of animals involved increase. Nevertheless, a good team of well-organised observers can easily cope with 750-1,000 animals per observer. The operational costs of the system average about 2,000 CFA francs per animal per year under the conditions prevailing in Senegal. This does not include the costs of research workers, nor such initial investments as vehicles, data-processing equipment, etc., which have a presumed lifespan of five years. It does, however, include fuel, transport costs, petty cash, the salaries of observers and the products utilised. These costs concern only the basic programme (modules for demography, growth, causes of death) but not additional investigations, the marginal cost of which varies, though is generally quite small.

**Data processing**

Individual surveillance soon produces a large bulk of data, depending on the population under study and the multiplicity of information recorded for each animal. Such data can be processed only by means of a computerised system.

The PPR programme, operating on a micro-computer, uses PANURGE data-processing software (4) which is derived from the “Multilog” database software.

By using PANURGE it is possible to consult automatically all new data as soon as they have been introduced, together with existing data already stored in various files. The new data can be validated immediately and can be manipulated by simple calculations (e.g. the interval between parturitions and mean daily weight gain) or, alternatively, they can be deleted.

**Reliability of the information**

As has already been shown, the reliability of information depends not only on the frequency and regularity of visits but also on the mode of recording and transmitting the information. Errors must be detected and corrected rapidly.

Information recorded in the field is transmitted directly to the data bank. The form used for recording information in the field is entered directly into the computer without any transcription. The identity of the animal concerned is verified by reference to the information already gathered; to promote uniformity in the replies given by different observers, every form consists of a closed questionnaire.
Early detection of errors is done at two levels:

- The observer keeps a file on all animals under his observation. In the office, the information gathered from the animals is transcribed into this file and certain errors (identity of the animal, name of the animal attendant, too-short intervals between parturitions, etc.) may be revealed. To correct faulty information, a return visit to the animals is necessary.

- The second control is done during data-processing. Detection of errors is automatic and any information incompatible with that already entered is rejected. The corresponding field file is then returned to the observer so that the necessary corrections can be made.

Simultaneous operation of numerous modules

Information derived from different modules can be brought together; because this requires synchronous operation, the observers in the field may be requested to follow many different recording protocols and must be provided with extensive training. In practice, animal husbandry technicians are perfectly suited to this type of work, although their competence naturally depends on personal motivation and organisational ability.

Keeping individual records in Senegal

In both the Sahelian climate of northern Senegal and the Sudano-Guinean climate of southern Senegal, a total of about 12,000 sheep and goats and 3,000 cattle have been identified and monitored according to the principles described above. Thus, the observations have been made in very different ecological zones and under different husbandry systems.

The oldest records derived from fortnightly visits date back to 1983. During a visit, the observer asks detailed questions, weighs livestock and performs various types of biological sampling. This repeated questioning is well-taken by the animal attendants, who have good relationships with the observers.

To give some idea of the importance of the data bank which has been formed, the following statistics covering five years are available for an annual population of an average of 1,000 sheep (including 500 ewes):

- 5,400 individuals identified
- 1,000 cases of mortality recorded
- 3,600 parturitions supervised
- 1,750 reproductive histories
- 3,750 growth histories.

THE BASIC NUCLEUS: THE DEMOGRAPHIC MODULE

This is the central module to which all others are linked. It contains the essential information on each individual and its movements, and provides precise data on population dynamics.
Knowledge of the individual

At the demographic module level, individual records provide two groups of information corresponding in the PANURGE data bank to the "status" and "reproduction" files.

The status file

The status file records the essential characteristics of the animal (sex and genetic type), together with the principal events and attendant circumstances of its life:

- birth: date, twinning, identity of dam
- entry: date, origin, age
- departure: date, age, nature (death or sale).

The pathologist will also find background information about the animal he is studying. He can learn, for example, the exact age of an animal, something which is often difficult to discover during epidemiological surveys. For such purposes, individual records are incomparable.

Knowing both the geographical origin of animals introduced and the movement of animals from one herd or village to another enables the pathologist to consider such factors.

The reproduction file

The reproduction file describes the reproductive career of each breeding animal:

- the reproductive cycle: dates of parturition, age at first parturition, interval between parturitions
- reproductive performance.

It also records events which affect female productivity (maternal qualities):

- abortion and stillbirth
- mortality of young animals up to three months of age.

Typical epidemiological studies of breeding diseases tend to relate the results of serological tests to the reproductive career of the female, usually recorded as a retrospective questionnaire (2). In fact, it is very difficult to obtain reliable and precise results in this field, particularly when dealing with small ruminants. While exact dates of parturitions may not be indispensable to this type of survey, it is essential to know about neonatal mortality and abortions. Experience has shown that, as far as stillbirths and neonatal deaths are concerned, an animal attendant remembers little about an animal that has spent only a short time in the flock or herd. Retrospective surveys, therefore, often underestimate early mortality.

Even in a flock under supervision, abortion is difficult to detect. However, precise knowledge of the interval between parturitions may provide an indication of an early abortion and thereby direct investigations to the animals at risk.
Knowledge about the population

One has become accustomed to regarding epidemiology as the science of denominators. In fact, after having recognised such health problems as disease, death and serological conversion, one is often confronted with the further problem of identifying the population involved in order to assess the importance of the situation.

By manipulating the data within the demographic module, precise information about the population concerned (the denominator) may be obtained.

The epidemiologist can adopt two approaches to a study of this population:

- the study of a focus of disease, which requires knowledge of the status of a population at a given date or during a given period;

- the study of a population in order to know its structure and dynamics.

Study of an outbreak

The animals present within a flock or village at a given date or during a given period are known with precision; information concerning size, sex distribution and age patterns in populations affected by an outbreak can thus be readily determined.

This allows the epidemiologist not only to calculate an attack rate, but also potentially to calculate attack rates by age groups and sex.

Of course, with the limitations concerning age determination already mentioned, this type of information could be obtained by a census of animals conducted once the outbreak has been declared. However, past history and events occurring before the outbreak can be investigated only by a retrospective survey dependent upon the memory of the livestock attendants. This method is not always reliable as facts tend to be exaggerated, either because their amplitude has captured the imagination of the animal attendant or because he wishes to justify himself to the visiting pathologist. Moreover, there is often massive disposal of animals when a severe epizootic commences and this naturally hampers an accurate estimation of population size.

Individual records created before the start of an epizootic provide the means to construct cohorts of animals in which all major events have been recorded. The starting date of cohort analysis may come well before the date on which an outbreak is declared, perhaps commencing with the arrival of a given animal in the herd or flock.

Study of a population

Information on population structure can be obtained by surveys; these surveys must be repeated, however, as population structure can vary greatly during a year. Even so, the data provided by individual records is vital for calculating the parameters of population dynamics. They make possible, at any rate, such analyses of population and population structure as entries and departures over a specified period, as well as the consecutive evolution (growth) of a herd or flock.

In addition, it is easy to obtain from the reproductive data mean values for:

- the interval between parturitions in relation to the number of parturitions;

- the relationship between the number of abortions and the number of births.
To describe mortality, individual records enable the determination of indices — “mortality quotients” (6) — which are easy to manipulate and accurately calculated. Unlike mortality rates calculated for an average population (an inadequate concept for populations which fluctuate considerably, as under traditional animal husbandry in Africa), these mortality quotients are calculated on the basis of initial or exposed populations (11) and correspond to the probability that an animal of a given age or sex will die in the course of a determined period, usually within a year. The cohorts on which the calculations are based correspond to generations, whereas mortality quotients are calculated by age group, sex or genetic type, making it possible to examine the effect of these factors on mortality.

Precise determination of these dynamic parameters is important not only for describing a population but also for comparing one population with another; for example, in order to assess the impact of a disease (1). Neither the structure nor the dynamics is usually fixed. Environmental variations from year to year may produce modifications in the dynamic parameters; it is therefore important to be able to follow them and appreciate their amplitude.

Comparison of populations

The comparison of global indices, calculated for different populations (for example, the global mortality quotient calculated for the entire population regardless of sex or age, or for the same populations at different times), can lead to erroneous conclusions through bias arising from different population structures.

This type of bias is corrected by making allowance for sex and age. The global index for the population is recalculated by applying partial indices (e.g. mortality quotients by age group and sex, to take the example cited above) to a standard population in which the proportions of the different age groups and sexes are determined.

THE PERIPHERAL MODULES: ANALYSES AT LEVELS 1 AND 2

Level 1: examination of variables provided by a single module

Level 2: simultaneous examination of variables provided by a peripheral module and by the demographic base module

On to the base nucleus are grafted peripheral modules, the functioning of which is the more rigorous because it relies on more precise demographic information.

Some of the protocols concerning epidemiology which are being developed, or have already been developed within the PPR programme, are listed here. This gives some idea of the range of research activities which can be incorporated into this structure.

There are two principle modes of enquiry:

- longitudinal enquiry (surveillance)
- time point enquiry.
Longitudinal enquiries are made:

- either by systematic recording of certain events to the extent that they occur (e.g. a disease)
- or by regular estimation of a parameter from a reasonable sample of the population (such as weight or serum titre).

Time point enquiries indicate the presence or importance of a given phenomenon, but not its evolution with time.

Analysis of data accumulated by a peripheral module can be done:

- either by confining processing to the module concerned (level 1 analysis)
- or by drawing on the data of the demographic module (level 2 analysis).

The latter is of better quality and greater value because it enables the epidemiologist to work with a demographic base for:

- analysis by age group or sex;
- prevention of interpretational bias due to different population structures during comparative analyses;
- determination of the denominator for calculation of rates and quotients.

In presenting the different peripheral modules, the results which can be achieved by analysis at levels 1 and 2 will be indicated.

Clinical surveillance

Module “causes of death”

Module “disease surveillance”

Module “respiratory disease surveillance”

Within the PPR programme, clinical findings are handled in one of three modules: causes of death, surveillance of diseases and outbreaks, and respiratory disease surveillance.

Causes of death

The animal husbandry technician is requested to indicate each cause of death, whether by malnutrition, growth disorder, accident or disease. In the case of disease, the technician attempts to specify the diagnosis by selecting from a list of nine syndromes on the exit form. To date diagnoses have been essentially clinical, with terminology referring to clinical signs and not to aetiology. A protocol for the systematic collection of samples for laboratory testing is currently being introduced, and this will provide better information on the responsible pathogens.

Analysis of data in this module taken in isolation (level 1 analysis) makes it possible to place the different causes of death in a hierarchy of major syndromes and their relative frequency.

When the data from this module are linked to the demographic model (level 2 analysis), the epidemiologist can measure the impact of each syndrome which produces
mortality and, with time, can follow variations. Impact is measured by an annual mortality quotient for each cause, either for all animals or for different categories of animals.

Year-to-year variations can be assessed for each syndrome by calculating the annual mortality quotient as it affects a standard population (9).

**Diseases and outbreaks**

For each notification of disease by the animal attendant, the technician completes a health surveillance form on which he records the evolution of the disease in an individual (noted on the form for individuals) or in a herd or flock (completed on the outbreak form).

Level 1 analysis can provide a complete list of the conditions encountered in a given zone.

For the more common conditions, it is possible to calculate a mortality rate and to confirm that the treatment adopted by the animal husbandry technician has modified this rate.

**Respiratory disease surveillance**

The preceding module does not record every case of disease. Some very common syndromes are considered to be benign by the animal attendants and are not reported to the technician. Systematic examination of each animal would be necessary for exhaustive coverage and recording every illness would obviously be most laborious. For this reason attention has been deliberately confined to a single group of illnesses, the respiratory diseases. In fact, pneumo-enteritis and diseases of the lungs are the principal diseases of small ruminants in the tropics, affecting a large number of animals each year in every ecological zone under study.

On fortnightly visits to the flock or herd, the technician examines each animal systematically for four symptoms: nasal discharge, cough, dyspnea and diarrhoea. This provides an exhaustive record for a given population.

Level 1 analysis of this module can be done for flocks and for zones:

- Within a given geographical zone, it is possible to calculate the rates of incidence and prevalence of respiratory diseases. Variations in prevalence demonstrate the seasonal character of these diseases;

- At flock level, such a protocol is valuable because it allows flocks to be classified by the frequency of respiratory disease. The mean prevalence of nasal discharge during any one season, calculated from the results of some 15 visits, can reveal large differences between flocks. However, considering that flocks are sometimes reduced to a single animal, it is hardly logical to calculate the mortality quotient for each flock.

Level 2 analysis relates the occurrence of these symptoms to the demographic parameters, particularly to mortality:

- For example, on the scale of groups of animals belonging to flocks in which the frequency of respiratory disease is identical, a link can be established between the mean rate of nasal discharge and the mortality quotient;
At the individual level, the relationship between the appearance and duration of respiratory disease and mortality can be examined.

**Growth and body condition**

*Module “growth record”*

*Module “body condition record”*

Whereas recording the body development of animals is principally the concern of livestock officers, it can prove useful in epidemiological studies.

It is recorded in two modules. The first, related to growth, was implemented at the start of the programme and is now fully developed, while the second, on body condition, is just being introduced.

**Growth recording**

Young animals born in the flock or herd are weighed regularly. Livestock officers study weight-for-age type relationships, average daily gain and factors affecting it (age, sex, season, genetic type, husbandry practices, etc.).

Level 2 analysis demonstrates the relationship between growth and mortality among young animals. If a link is established between these two indicators, it can provide a health warning for a given age or season, derived from weight increment data.

**Body condition recording**

The body condition of adult females is gauged by palpating the lumbar region. A scale of points adapted to local animals is being developed.

There is probably a relationship between the body condition of ewes and their reproductive performance, as well as between body condition and susceptibility to infections. These hypotheses will be analysed from records of body condition obtained in the field, utilising the physiological status of females (in the demographic module) and the appearance of clinical illness in the flock (in the disease surveillance module).

It would be interesting to discover if a change in body condition increases the risk of abortion or stillbirth. The development of a warning threshold for use in deciding whether to supplement the diet at the end of the dry season should be possible.

**Laboratory tests**

Laboratory test protocols have been developed for application to individual animals and to geographical zones.

*Application to geographical zones*

- Module “faecal examination”

The module for tests on samples of faeces provides information on the kinetics of helminth infestation of sheep which are classified by zone, season and age. This information derives from regular examination of faeces from a sample of animals.
Processing of the data for this module (level 1 analysis) provides information on the parasitic environment in which the animals live. The results cannot be linked to the performance of individual animals, but they can be linked to data for a particular group of animals.

This module can also be used to interpret the efficacy of anthelmintic treatment (see below).

**Application to individual animals**

- Module "serological kinetics of respiratory disease pathogens"
- Module "diseases of breeding"

Application of the results of laboratory tests to individual animals leads to a much finer degree of interpretation than that of a group of animals, since individual results rather than group averages are employed.

Two modules, dealing with diseases of breeding and the pathogens of respiratory disease, are currently available.

- **Diseases of breeding**

  All female animals over one year old are subject to a programme of single serological testing for the principal diseases of breeding: brucellosis, chlamydiosis, Q fever, toxoplasmosis and listeriosis.

  Current analyses will provide information on the prevalence of each infection and will reveal any possible mixed infections associated with these pathogens (level 1 analysis).

  Level 2 analysis, drawing on the status file, will provide a distribution of the various infections by age group.

  When linked to the file on reproduction, the serological responses of each female can be related to its reproductive career, both before and after taking the blood sample.

  This analysis will therefore be both prospective and retrospective. The retrospective approach does not involve questioning the animal attendant, but rather entails the more reliable procedure of interrogating a data bank.

- **Pathogens of respiratory disease**

  Lambs and kids born during an 18-month period have been the object of a serological survey aimed at establishing the kinetics of infections by the principal infectious agents of respiratory disease (8): peste des petits ruminants virus, parainfluenza-3 virus, ovine adenovirus type 5, IBR virus, respiratory syncytial virus, *Chlamydia*, *Mycoplasma* strain F38, *M. capricolum*, *M. m. mycoides* strain 1c, *M. capri*, *M. ovipneumoniae*, *Pasteurella multocida* types A and O, and *P. haemolytica*. Serum samples are taken at intervals of 45 days between 15 days and 12 months. A sample is also taken from each dam when her offspring are first sampled.

  Analysis of the data in this module (level 1) will provide information on:
  - the incidence of the various infectious agents
  - their combinations (in order of appearance)
- the kinetics of antibodies in individual animals
- the serological response of young animals in relation to that of their dams
- the evolution of titres within a herd or flock
- the seasonal variations.

Level 2 analysis will provide evidence of relationships between infection with various agents and mortality among young animals.

**Study of husbandry conditions and practices**

*Module “housing and feeding”*

*Module “feed supplementation”*

*Module “milking”*

**Housing and feeding**

The purpose of this module is to describe the environment in which the animals are kept. It is applied in the first instance to groups of animals, namely the concessionary herds or flocks.

It deals with:
- housing
- the type and use of grazing land
- the type and destination of feed supplementation
- watering
- the surveillance of the animals.

The information is collected twice a year, during the dry and rainy seasons, and is repeated annually.

Level 1 analysis provides a classification of herds or flocks by the criteria given above.

Level 2 analysis seeks relationships between housing and feeding conditions and the demographic parameters; for example, one could determine if certain types of housing were associated with a higher mortality than others.

**Feed supplementation and milking**

The module “housing and feeding” covers all zones, but for the Sahelian zone it is apparent that the effects of supplementation and milking are especially important. A decision to study these practices in greater detail by creating two specific modules, which are accounts of husbandry practices rather than survey protocols, was therefore taken.

The animal attendant records on a form the type and quantity of feed distributed each day and the amount of milk collected. During their fortnightly visits, the animal husbandry technicians make notes on the animals which have received supplements and those which have been milked; they also inspect the forms completed by the animal attendant.
By combining the information obtained with demographic parameters (level 2 analysis), it should be possible to discover which supplementation or milking practices are detrimental to the health of the offspring of ewes or goats up to three months of age.

Such modules concerning husbandry practices would also be valuable for interpreting the other peripheral modules.

**INTERRELATIONSHIPS BETWEEN PERIPHERAL MODULES: LEVEL 3 ANALYSIS**

*Level 3: simultaneous examination of variables originating from two or more peripheral modules and the demographic module*

The detailed information which can be obtained from each peripheral module either by analysis of variables in isolation (level 1 analysis) or in combination with data from the demographic module (level 2 analysis) has been shown by the description of peripheral modules. As has already been mentioned, the information contained in one peripheral module can be valuable if combined with that of another.

There are two ways in which the peripheral modules can be linked:

– by the transfer of results from one module to another after processing the data;

– by the transfer of the variables from one module to another.

PANURGE software allows the variables for a given animal, even if they are kept in different files, to be transferred directly so that the joint processing of data present in different peripheral modules is facilitated.

Analyses conducted jointly on variables from two or more modules and the demographic module are called level 3 analyses.

These analyses help the epidemiologist to supplement epidemiological variables with variables defined by other disciplines, and thereby to work in a truly interdisciplinary system.

What follows are examples of how linkage between the variables of different modules prove their value for epidemiological studies.

**Appreciation of the value of an indicator**

Linkage between the modules for respiratory diseases, causes of death and demographic survey has revealed a relationship between the mean prevalence of nasal discharge and the quotient of mortality from lung disease. The first indicator (nasal discharge) can therefore be used to estimate the occurrence of lung disease in a flock. (Note that the second indicator, the quotient of mortality from lung disease, cannot be calculated for a flock.)

**Aetiological research**

Joint analysis of the respiratory diseases and respiratory disease serology modules may make it possible to identify serological conversions associated with nasal
discharge, lung disease and/or diarrhoea. This allows the role of each pathogen, in the origin of respiratory disease, acting alone or in combination, to be assessed.

Estimation of losses associated with a given disease

By linking the growth and respiratory disease serology modules, it should be possible to follow changes in the growth curve of an animal in relation to serological conversion. This information could be used to assess losses, in terms of average daily gain (ADG) or per kg of body weight, attributable to a given pathogen or combination of pathogens.

Study of risk factors

Flock data for the mean prevalence of nasal discharge have been linked to the variables of the housing and feeding module in order to discover environmental conditions which are risk factors in respiratory disease.

INTERVENTION AMONG LIVESTOCK: LEVEL 4 ANALYSIS

Level 4: simultaneous study of variables derived from one or more modules, following experimental modification of certain features of the husbandry system

In the preceding levels of analysis, the investigation was conducted in an environment which was assumed not to have been altered by the observer. The proposed system of investigation can also be used to evaluate the effects of changes introduced by the experimenter.

The analysis utilises:
- variables from the demographic module
- variables from one or more peripheral modules
- one or more variables which have been altered.

Level 4 analysis can be used to evaluate improvements in husbandry and for aetiological investigations.

Evaluation of improvements

Attention was first paid to prophylactic schemes for small ruminants (vaccination against peste des petits ruminants and pasteurellosis, and treatment for strongylid nematodes). In addition, taking into account the importance of supplementary feed in the Sahelian zone, many different supplementation strategies will be evaluated during the next dry season.

To examine prophylactic schemes flocks were divided into four groups, each comprising animals from the same village, as follows:
- control group
- wormed group
- vaccinated group
- group both wormed and vaccinated.

The effects of anthelmintic treatment and vaccination were evaluated by comparing variables in the demographic module (mortality and reproduction) and the "causes of death" and "growth" modules. This mode of grouping was effective, although difficulties were created by variation in husbandry practices both among villages and within the same village.

By using the information contained in the "housing and feeding" and "supplementation" modules, it would be easy to make a rational selection of flocks to give homogeneous groups for the experiment. This is another use of relationships between peripheral modules.

**Aetiological research**

Although the plague syndrome (pneumonia and enteritis) is rarely observed among sheep in Senegal, vaccine against peste des petits ruminants has been tried in that species in order to discover its effect on the incidence of respiratory disease.

The prevalence of respiratory disease and mortality from lung disease was lower in the vaccinated than in the unvaccinated control group; it may therefore be concluded that the virus plays a major part in lung disease, even in the absence of typical clinical manifestations of peste des petits ruminants.

**DISCUSSION**

The system described makes it possible to investigate the major branches of epidemiology, but it does have some limitations.

**The major branches of activity in epidemiology**

Three branches were defined at a WHO epidemiology symposium held in 1968. The four levels of analysis function differently in each of the branches, as follows:

- *Defining the extent and distribution of morbid phenomena.* Analyses at levels 1 and 2 furnish precise information on mortality and morbidity in the supervised herds/flocks in the three zones of surveillance. To some extent, taking into account the limitations of the method, the results can be extrapolated to all small ruminants in Senegal.

- *Discovering aetiological factors in order to devise control measures.* Analyses at levels 2 and 3 make possible the formulation of aetiological hypotheses, making use of the risk factors, while causal relationships can be revealed by levels 3 and 4 analyses.

- *Gauging the efficacy of improvements.* Level 4 analysis is designed to deal with this aspect.
Limitations of the method

There are three principal limitations:

- **Spatial homogeneity of the epidemiological situation**

  A sample of villages selected from the three zones of Senegal is under surveillance. Better information on morbid phenomena would be provided if their spatial distribution was homogeneous, at least within a given ecological zone. However, the system could fail if the morbid phenomena were localised in distribution or if the distribution was very uneven within a zone; the villages surveyed might be those either most or least affected within a zone. The sample, therefore, cannot be representative and the results cannot be extrapolated to the entire zone.

  This mode of surveillance is unsuitable for an epidemiological study of rare diseases, for there is far less probability of encountering such diseases within the flocks surveyed than there is of finding the same diseases in the territory as a whole. However, the system is still useful for examining the aetiology of rare diseases.

- **Relativity of the concept of "virgin territory"**

  Analyses conducted at the first three levels presuppose the absence of interventions by the observer, while for level 4 analysis (experimentation) it is preferable to have a control group.

  Such a concept of "virgin territory", theoretically indispensable, is only relative in practice whenever investigations are made in the farming sector. To supervise a flock without providing some input is impossible, for if the animal attendant derives no benefit from surveillance he will sooner or later withdraw his support. Moreover, when a severe epizootic occurs, one cannot be expected to remain passive and refrain from intervention. This would discredit the system and would be contrary to the first rule of surveillance: to establish bonds of mutual respect, and even friendship, with the animal attendant. The problem, therefore, is how to maintain a delicate balance between minimum intervention and the confidence of the participants. One of the best solutions is to intervene whenever necessary when species other than that under surveillance (such as horses) are involved. This solution satisfies the animal attendant without altering the object under study, and it maintains credibility for effective treatment, which is the best "visiting card" in the traditional livestock sector.

  For trials, a major problem is the choice of the type of intervention applied to premises "A", so that premises "B" are not placed at a disadvantage. The placebo technique, established practice for trials, should be adopted whenever possible, but there must be no risk of ruining the scheme by detection.

  In the absence of strictly virgin territory, it is important to supervise the interventions of observers in order to be able to interpret subsequent findings. Finally, as soon as "virgin territory" is not absolutely indispensable, the situation can be improved rapidly by applying an effective amelioration to all flocks, thereby consolidating the good relationship between the observer and the animal attendants.

- **Feasibility of the model**

  The quality of the proposed model depends on its duration and the regularity and thoroughness of surveillance must be understood. These conditions are particularly difficult to fulfil; to do so, thorough training and selection of field agents are necessary.
CONCLUSION

The authors wish to emphasise that the system of investigation presented herein is not the only tool available to the epidemiologist; it is, however, capable of providing valuable and novel elements to support his reasoning which, in turn, can lead to a fresh approach to problems and to the validation of results. If this succeeds, the many exchanges of acquired information and shared knowledge could further an interdisciplinary approach in which each discipline retains its specificity while sharing data, analyses and conclusions with other disciplines.

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A set of four Appendices accompanies the French version of this paper (model Exit, Health Surveillance, Outbreak and Respiratory/Digestive record forms). Translations of these forms may be obtained from the OIE on request.

REFERENCES


