CHARACTERISTICS OF LIVESTOCK PRODUCTION AS DETERMINANT OF FOOT-AND-MOUTH DISEASE ECOSYSTEMS

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SUMMARY

The functionalist approach predominant in the animal health field appears limited when it comes to the overall regional characterization of existing problems and to propose the necessary integral solutions. Consequently, even when quantitatively positive results have been obtained in the majority of the animal health programs in Latin America, the major features by which diseases are produced and distributed have rarely been substantially modified.

The qualitative consequences of virus-host interaction (symbiosis, adapted parasitism, disease, death) hinge basically on interspecific coevolution, so that the host population generation span, --measured in terms of the length of time spent within the ecosystems-- will constitute a preponderant factor in the production and distribution of foot-and-mouth disease (FMD) and its socioeconomic and political effects.

In turn, the stability or the fluctuations in the populations of the susceptible species, as well as their structure, density, etc., are closely linked to the historical process of socioeconomic and technological development of the countries which, in South America, have created a geographic division of the types of livestock exploitation according to the needs and tendencies derived from that development process.

Four types of economic activity (extraction, transformation for meat, transformation for milk, and subsistence livestock raising) thus occupy their own peculiar geographic and technological areas which result in different forms of cattle production management and, therefore, of the socioeconomic relationships existing among them. In the final instance they determine the regional behaviors of FMD. It is believed that this approach will permit a new orientation for the identification, analysis and solution of health problems in an integral context that contemplates the productive aspects in relation to the availability and distribution of livestock products.

I. INTRODUCTION

Foot-and-mouth disease (FMD) control programs in South America have traditionally been based on massive systematic nationwide vaccination campaigns, complemented by other activities to which a secondary importance has been assigned. The strategies as well as the tactical and operative aspects of these campaigns are founded on a functionalist concept of diseases according to which the epidemiologic factors --virus, susceptible host and the environment-- are linearly associated without considering their interaction within an overall environmental context in a given place and time.

The concept of FMD ecosystems was developed by Rosenberg and Goić (*16*) in 1973. Briefly, four types of areas were distinguished according to the possible interactions between the susceptible species and the virus (free, sporadic, secondary endemic and primary endemic). General principles were established for control strategies which aimed at modifying those interactions so as to obtain free areas or areas of sporadic occurrence (*16*). Later, the concept of FMD ecosystems was extended to include other acute communicable animal diseases, with particular attention to the ecological conditions as determinants for the displacements of sources of infection and of susceptible individuals responsible for the different epidemiological behaviors of the diseases (*13*). This ecological approach was recently enlarged and applied to the development of regional strategies for the control

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of FMD in South America (*14*). Although this development represents an advance in the conceptual uniformity of the majority of communicable animal disease control programs, it does not emphasize to the degree necessary the role of socioeconomic and cultural factors in determing the ecological conditions responsible for the behavior of infectious-contagious diseases.

This paper proposes to complement the predominantly biological approach now in use by adding to it several factors related to the structure of livestock production as determinants of the occurrence, spread and maintenance of FMD.

II. ECOLOGICAL APPROACH

From the ecological viewpoint, FMD can be described as one of the possible qualitative changes resulting from the interaction between two or more species in a given environment, other possible situations are adaptative parasitism and symbiosis. In general, when host species and parasites coevolve over time in slightly variable environmental conditions, the qualitative changes tend to become less injurious to the host. A relationship of mutualism may then be achieved (*10*).

Haldane (*6*) summarizes the results of the interactions among species according to the degree of stability of the host population: the exploiting action of an agent on a fluctuating population results in disease while in a stable population it tends to develop a situation of "adapted parasitism" (Table 1). The coevolution between some species of ruminants and the FMD virus must be understood in terms of generations, not in philogenetic terms, although the facility with which the carrier state is established in asymptomatic individuals would lead one to believe that the interspecific relations have existed for a long time (philogenetic coevolution).

The carrier state has been described in cattle, sheep and in bubalines, but not in swine (*15*). An evolutive interaction without marked qualitative changes in the host species is possible only when the latter has a sufficient degree of stability to enable a large number of individuals to develop mechanisms of resistance to the endemic viruses. This would not be possible in swine due to the short halflife of their populations in commercial production. Therefore, even when the viral populations are able to develop rapid selection mechanisms --due to the large number of replications they carry out in a short time-- that result in strains with characteristics different from the original ones (*3, 4, 5, 8*), it is the generation span of the host population which, in the final analysis, determines the pathological consequences of the infectious process.

TABLE 1. *Interspecific interactions and their results*[a]

Type of host-parasite relationship	Fluctuating populations	Stable populations
Unilateral exploitation	Diseases	Adaped parasitism
Mutual exploitation	—	Symbiosis

[a]Taken from Margalef, R., 1974, who quotes from J.B.S. Haldane. Symp. fattori especiazione animal, Pallanza, 1949.

Livestock are raised in South America mainly in regions of prairies and savannahs where the domestic ruminants replace other primary consumer species that have been deliberately exterminated by man or reduced both in numbers and varieties through the competition established for the control of ecological niches.

The domestication of the species is based on the selection of the most suitable characteristics for production. In order to maintain them, man must interfere to prevent the reappearance of undesirable ancestral characteristics and provide suitable environmental conditions for the best manifestation of the selected characteristics. This means that the ecosystems and the populations are tampered with in order to orient them to man's objective of "maximum production" in opposition to the strategy of nature of "maximum protection" (*10*). In this way man's interference in the ecosystems, through the introduction of external

energy sources, renders them intrinsically unstable even when certain formations can maintain relatively fixed characteristics over several human generations. In synthesis, the fluctuations to which the domestic animal populations are subjected are the result of the relationship between the natural interactions characteristic of the ecosystems and those which are a consequence of the energy input that man has made to the ecosystem through the productive processes.

III. SOCIOECONOMIC APPROACH

The practices of agricultural and livestock production and commerce are determined by ecological, socioeconomic, cultural and geopolitical factors expressed in the technology applied and in the degree to which that technology modifies nature. The growth of cities, as a consequence of industrialization and of the expansion of the tertiary sector, has created centers for the consumption of agricultural and livestock products that must be secured from distant production and preparation sites, often even outside the borders of the industrial countries. As a consequence of this phenomenon, a division or specialization of the types and forms of production occurred in the livestock sector: breeding activities dominated in some regions, fattening in others, and milk production areas were established in the proximity of the milk consumption or processing centers.

With the appearance of the cold storage and meat packing industry, livestock fattening became a more profitable activity as feeding spans and animal lifetimes were shortened. Fattening and finishing was done in high-yield prairies based on good quality natural pastures, permanent or seasonal artificial fields and stubble fields. Breeding activities on the other hand, occupied lesser quality fields or areas more distant from the urban centers. This was a consequence of the lower and slower profitability of the animal as capital (breeder bulls, cows), when compared with the animal as a product (mainly steers and bullocks). Consequently, properties utilized for cattle raising expanded in size through the incorporation of marginal lands or lands "sidelined" through the extractive exploitation of depleted agricultural and forestry resources. The development of railroad and highway infrastructure and the means of transportation contributed to the establishment of certain agricultural and livestock activities that generally took into account the most appropriate ecological and climatic conditions. This accented the regional division of the types of exploitation. Cold storage and meat-packing plants and the availability of short-term bank credit also contributed to speeding up the differentiation process: concentration of the product animal and dispersion of the capital animal.

This typology excludes intensive fattening (feed-lot) activities, which are only slightly developed in South America. Man's energy input in feed-lot activities is maximum. As such, the protection of the animal's productive state depends almost exclusively on the technology applied, the effects of which are immediate.

As a result of the factors by which they are determined, the anthropogenic ecosystems including the domestic populations, are subject to variations derived from socioeconomic, cultural and geopolitical influences that overlap the climatic conditioning. Some modifications are of local origin, derived from changes produced within the region itself; others originate from decisions taken at the national policy-making level. Others, finally, are dependent on factors determined by international policies and commerce. The building of a highway, for instance, which is carried out on the local level no matter where its decision may have been taken, can produce very important ecological and sociogeographic transformations affecting the processes of production and on the agricultural and livestock commerce. This impact may momentarily or permanently destabilize the livestock population by affecting their structure and dynamics.

Changes in farming policies, determined at the central government level, also have immediate effects even though they generally act over the medium or long term to encourage or discourage a given productive or commercial activity. This also has repercussions on population stability. Modifications of conditions on the international market for agricultural and livestock products may also have no less striking effects on the livestock populations of

the countries that export meat, wool or other farm products. Abrupt variations in prices and demand are felt first in the animal fattening areas, affecting later the extractive exploitation areas whose populations are slower to change because they are composed of animals held in form of capital.

All these changes will eventually impact --sometimes very deeply-- on society as a whole, as they modify the labor processes and the production relationships. In turn, this could have a marked influence on the animal health policies or their receptivity at the community level. Figure 1 depicts the interactions among the local ecological and socioeconomic factors, the national policies and international policy and commerce, with respect to livestock populations.

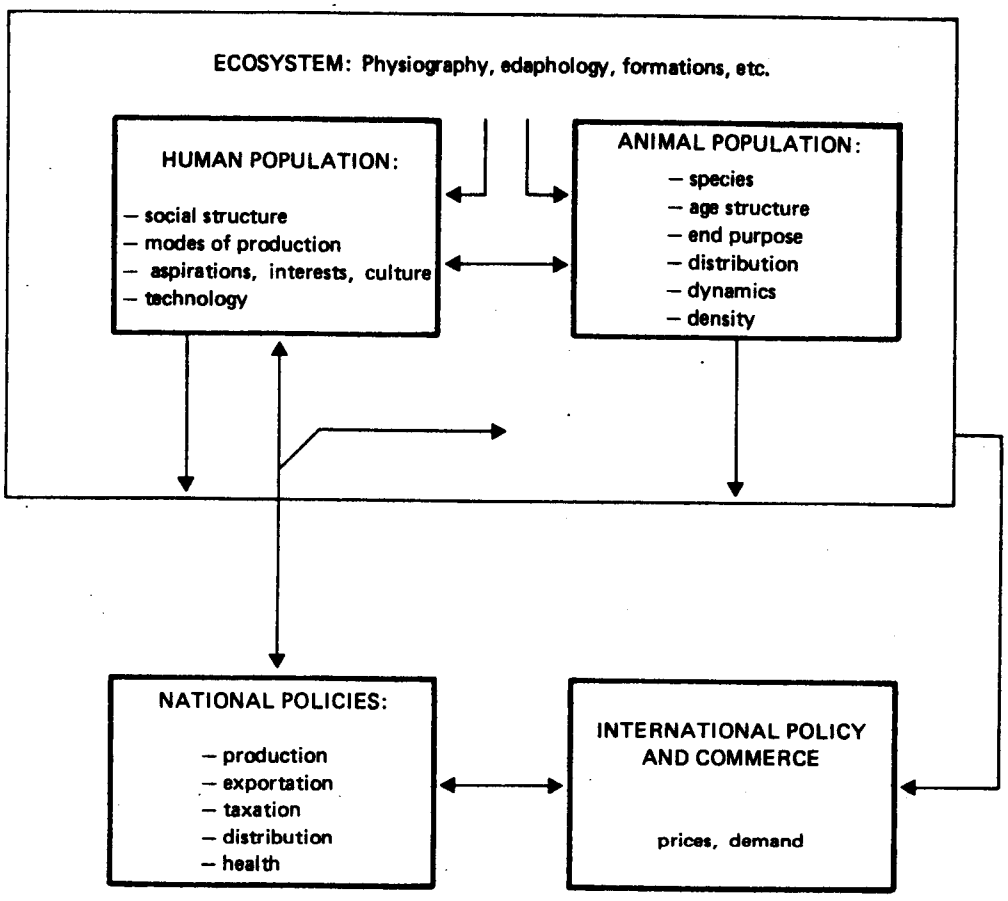

FIGURE 1. *Schematic representation of the interactions between the animal populations and the ecological, socioeconomic, political and commercial factors that influence them.*

IV. LIVESTOCK PRODUCTION STRUCTURE AS DETERMINANT OF FOOT-AND-MOUTH DISEASE ECOSYSTEMS

The distribution of FMD in South America coincides rather closely with the distribution of cattle. This does not, however, exclude the possible importance that other domestic or wild species may have in maintaining and spreading the disease in the ecosystems, although it is quite possible that cattle by itself are able to maintain virus endemicity without the intervention of other species.

The predominant FMD transmission mechanism takes place through the contact between animals, excretors of an aerosol mist containing at least one infective dose of virus and a susceptible host exposed to the aerosol. The FMD virus' inability of remaining for long periods outside an appropriate host makes its maintenance in the ecosystems mainly dependent on the behavior of the susceptible populations (*12*); since these populations are in turn conditioned to the way the human communities handle them, these communities' characteristics will influence the virus-host interactions and thus definitively determine the consequences of the interaction process.

The ecological, socioeconomic and geopolitical factors explain and determine the epidemiological behavior of FMD, so that their analysis enables regions to be characterized as true ecosystems with relative independence of the quantification of the disease therein.

These ecosystems, defined through the characteristics of livestock production, coincide with previously described ecological definitions (*13, 14, 16*) without excluding the possibility of making subclassifications of microsystems at the local level on the same bases (*9*).

Four types of economic activities characteristic of livestock exploitation in South America and the FMD ecosystems thus determined are described below. Although this classification may recognizedly suffer from a certain degree of simplification and schematism, it serves the purpose of exemplifying the role of the socioeconomic structure as a preponderant factor in the determination of the disease.

1. Extractive livestock economy

Extractive economic activities correspond to regions of extensive cattle raising with a predominance of purebred or crossbred beef-producing animals. Due to the factors already mentioned, the extensive cattle raising is done on large properties having large herds and low population density. They occupy vast, marginal regions of prairies and plains and are exporters of finished or unfinished calves or steers. Importation of animals is limited to a small number of bulls and cows for breeding and upgrading purposes, although it is more common to employ stud and breeder animals raised on the establishments themselves or on ranches in the same general region. Feed is usually based on natural pastures or low-yield permanent artificial prairies that have in many cases replaced the native forest species. Man's contribution in terms of infrastructure is slight and the cattle are often moved to the fattening fields or to slaughterhouses in droves that take a substantial length of time. The reinvestment rate is very low and a large part of the benefits is invested in economic activities unrelated to the livestock raising effort. Miniranches, colonization and settlement areas and native communities may exist jointly with the large ranches; nevertheless, due to their characteristic modes of production, these human groups do not modify the extractive production system as a whole.

The socioeconomic influences external to these regions are slow acting and the technology applied is conditioned to the extractive primary economy characteristics peculiar to the land ownership structure, the ecological conditions and the distances to the areas of livestock products processing and consumption.

Corresponding to the previously described primary endemic ecosystems, the agent therein would be maintained permanently, whether diffused throughout the greater part of the ecosystem or distributed in patches in some cattle clusters. The animal populations are stable enough to ensure development of the ontogenic coevolution between the individuals and the viral replication cycles. The stability of the populations is ensured by the nature of the livestock exploitation

predominant in the ecosystem; extensive breeding and raising, low regional density, cattle clusters with low turnover rates and limited human interference.

Low population fluctuations are due almost entirely to local factors: seasonality, periodic outflows, changes of grazing areas or pasture grounds, internal commerce.

The infection would be sustained by the passage of small doses of virus among relatively immune individuals, thus ensuring an adequate infection rate with little or no morbidity. The populations of susceptible wild species may intervene in parallel cycles or ordinary cycles as epidemiological or ecological reservoirs; in this regard, there is a striking coincidence between the distribution of capybara (*Hydrochoerus capibara*) in certain parts of South America with the areas considered as primary endemic areas (*17*).

Occasional wider population fluctuations, through increase, decrease or alterations of structure, produce changes in contact rates and in population susceptibility. The local or regional population increases are the common reply to droughts, floods, population surpluses unmarketed because of changes in market values, or ecological modifications resulting from highway or railroad works, dam works, etc. These increases would lead to greater contact rates with temporary increase in morbidity. Occasional epidemic waves are aggravated when these factors coincide with the introduction of agents exotic to the ecosystem. Since in the primary endemic areas FMD as a disease is usually not a significant limiting factor with regard to production, due to the low regional density and to the host population prior experience with endemic viruses, the resulting morbidity is considered as "normal". Decrease in the size of the populations, as a result of mortality related to infectious, parasitic or nutritional diseases or caused by exaggerated extraction of production, or as a consequence of extemporaneous floods or droughts, would bring a similar drop in the contact rate, subclinical infections and population immunity. This would then be followed by an increase in the herd susceptibility.

The combination of the factors that determine the fluctuations in the populations would condition the virus-host relationships and their result either unapparent parasitism or overt disease. By the very nature of the factors involved, the presentation of the disease does not show marked seasonal tendencies although it appears with a certain cyclical pattern reflected mainly in other areas that receive cattle from these ecosystems (*16*). It is common for outbreaks to occur in droves moving out from ranches and bound for fattening or finishing fields or slaughterhouses, or even within the ranches right after branding, selection and separation, weaning or vaccinating operations. These outbreaks customarily affect young animals.

Examples of primary FMD endemic ecosystems would be found in the typical extractive cattle raising regions of South America, such as Brazil's "pantanal" area in the State of Mato Grosso and along the southwest border region in Rio Grande do Sul, the "chaco" region of Paraguay and northern Argentina and the "llanos" of Venezuela and Colombia.

2. Meat transformation mixed economy

This term is being used to describe an economic activity that although esentially primary livestock production is based on the semitransformation of the animal removed from the breeding zones into a product for slaughter and conversion into meat. Commonly, commercial activities frequently utilize the animal as a value of exchange or speculation through mechanisms such as auctions, shows, livestock markets or direct selling negotiations.

This type of exploitation, corresponding to cattle fattening or semi-intensive finishing, generally is performed in areas of good natural pastures relatively near the processing and consumer centers and is often complemented by extensive, short-cycle agriculture. The cattle are fed on natural or improved pastures and permanent or seasonal fodders; leguminous and grain stubbles are also utilized. Medium-size establishments predominate and there is substantial subdivision of pastures into small feeding areas. The stock --calves or steers, according to the region-- remains on this productive process for only a short time; the age

of the stock averages from 1.5 to 2.5 years in the majority of cases. The bovine population has a high annual turnover rate which often reaches 100%. Its most important characteristic is the intense mobilization of animals, whether those coming in from breeding or milk-producing areas, those moved out of the area bounded for slaughterhouses and packing-plants, or those inbound from shows and other places of commercialization.

The population fluctuation is also conditioned by national and international economic factors to which the local economic and financial systems are highly sensitive. Changes in meat values on the national or international markets have immediate repercussions on the volume and selling value of the populations, either encouraging or discouraging the fattening and finishing activities. Also, the profitability of livestock raising as compared to agriculture determines the amount of land area dedicated to either of the activities; since areas with good soils are usually involved, the switch from one activity to another is relatively easy and can be accomplished in a short time. Rail and highway systems are generally good and a large percentage of the cattle can be moved by truck or train.

Dairy farming activities that do not modify the general tendency toward fattening and finishing beef cattle may exist in these regions, in the areas surrounding the towns and cities or in zones under the influence of milk-processing plants.

The epidemiological behavior of FMD corresponds to that described for the secondary endemic (*16*) or epiendemic ecosystems (*13, 14*) wherein virus presence is ensured by the double mechanism of infection sources and susceptible hosts coming in from other ecosystems. This situation leads to the appearance of numerous clinical cases which become new sources of infection with subsequent increase in the effective contact rates in populations having high regional and herd densities.

The affected herds rate is usually high and since the inbound flow of infection sources and susceptible hosts has a seasonal character determined by climatic, agricultural and market factors, the development of the disease has a marked seasonal characteristic. Systematic vaccination finds it difficult to eliminate FMD totally from these ecosystems, due to the susceptible population's short age and high turnover rate.

High land profitability, the need of making lands available for annual plantings, taxes, credit charges and the compulsory quarantine of affected herds contribute to determine large losses due to FMD in these areas where the socioeconomic impact of the disease is highest.

This impact is reflected mostly at the national level because of the close relationship between these areas and meat-exportation activities, which has historically been one of the critical motivations behind the investments dedicated to the campaings against the disease.

Typical examples of such areas are the humid Argentine pampa and the fattening areas along the southern border of Rio Grande do Sul and the western border of the State of São Paulo in Brazil.

3. Milk production transformation economy

As another of the variants of the primary economic activities related to livestock raising, the transformation economy for milk production is defined in this work as the livestock farms dedicated to the exploitation of dairy herds for intensive and semi-intensive milk production; they are found in the geographic areas near the centers of industrialization. In the majority of countries this type of production depends on third-party product commercialization and, as such, is subject to economic and political influences from outside the primary activity itself. Frequently, dairy production coexists with vegetable and other farming activities producing fruit, vegetables, eggs, etc., for direct consumption or for the food processing industry.

Good transport and communications systems exist in these areas and the dairy farming activities, which are normally technologically oriented, have adequate facilities available. The herds, small or medium sized, have a slow population turnover --capital animals are involved in dairy farming operations-- and the movement is slight unless there are meat-packing plants or large slaughterhouses in the region.

Even when some livestock fattening activities coexist in certain dairy areas, the disease's behavior

is hard to differentiate from what is observed in the subsistence economic structures analyzed next on in this paper; nevertheless, the commercialization of milk can play an important role as a virus transmitter during epidemic outbreaks (*2, 7*).

4. Simple mercantile economy

a) Complementary livestock raising

Few cattle are usually raised in areas where vegetable farming and fruit growing are predominant; the availability of animal feed is restricted by the need to obtain maximum utilization of the land for intensive agricultural activities. Cattle are thus, used in a complementary way to furnish milk and traction (labour). Depending on market conditions and feed availability, pig breeding and/or fattening may be pursued with varying degrees of herd size and technical know-how. This activity could range from feeding pigs on human garbage, wastes produced by meat-packing and dairy industries and agricultural surpluses, to highly selected pig herds raised in advanced technological conditions.

b) Subsistence livestock raising

This type of livestock production is characteristic of marginal communities and can be found in two forms: one, in areas intensely subdivided into low productivity minifarms with depleted lands, where the bovine gives way to the pig or to smaller ruminants; the second, a community type organization made up of higher productivity minifarms utilizing community-held fields for animal pasture. The conditions of the first form are similar to those of the complementary operation; those of the second form generally constitute the typical example of rural farming areas based on a simple mercantile economy.

Both the economic activities of transformation for milk and the subsistence economic activities determine occasional appearances of FMD, represented by the sporadic (*16*) or paraendemic (*13, 14*) ecosystems. The population stability as a whole is high in these systems since the herds are largely composed of adult animals produced on the establishments themselves or on other establishments within the zone. Incoming animals are limited to a few cows, bulls and some steers and oxen for local supply. Nevertheless, some of these regions may have meat-packing plants that create seasonal flows of cattle coming in from other regions and determining the existence of fields where cattle is kept for short periods whenever the number of inbound animals exceeds the slaughtering capacity. The regional density of bovines is low because there is generally a checkerboard distribution of agriculture farms and dairy farms, although the density could be very high at the herd level.

Given the low interchange of cattle, its low regional density and the impossibility of pigs maintaining the infection much beyond the duration of the clinical episodes, the virus' stay in the animal population is shortlived. This means that the virus finds neither the population density nor the passage possibilities required to remain at an endemic level. The sporadic occurrence of the disease will be related to the ingress of animals or by-products and generally reflects the diseases's behavior in other ecosystems of a country or region.

The appearance of FMD in some pig herds fed raw milk by-products or wastes from the meat-packing industry often constitutes the index case.

V. RELATIONSHIPS AMONG THE LIVESTOCK ECONOMIC STRUCTURES AND THEIR IMPACT ON FMD EPIDEMIOLOGY

As described previously, the historical development of the economy in South America determined the division of the type of livestock activity into different geopolitical areas. This division not only happened at the national level but also at the subcontinental and world levels.

Due to its geographic, ecological and economic (reduced reinvestment) limitations, the extractive livestock economy displaced to areas farthest from the urban centers, requires specific areas for the fattening or finishing of cattle bound for slaughter. The fattening operations require good lands in order to be profitable; the frequently alternated utilization of prairies for pastures and for temporary

crops, does not allow for the animals' presence for prolonged periods of time.

The origin (endemic areas) of cattle raised for finishing purposes ensures a permanent influx of infection sources and/or susceptible hosts into areas of high population density, with the consequent appearance of more intense outbreaks disseminated during marketing seasons particularly when new animals at the start of their fattening period are put together with fattened steers at the end of their cycle. A possible endemic presence of the virus in sheep populations may be added to this process.

Occasional movements of discard animals, breeder bulls or oxen toward the dairy or subsistence economic areas ensure the wide diffusion of the infection during epidemic periods (Figure 2).

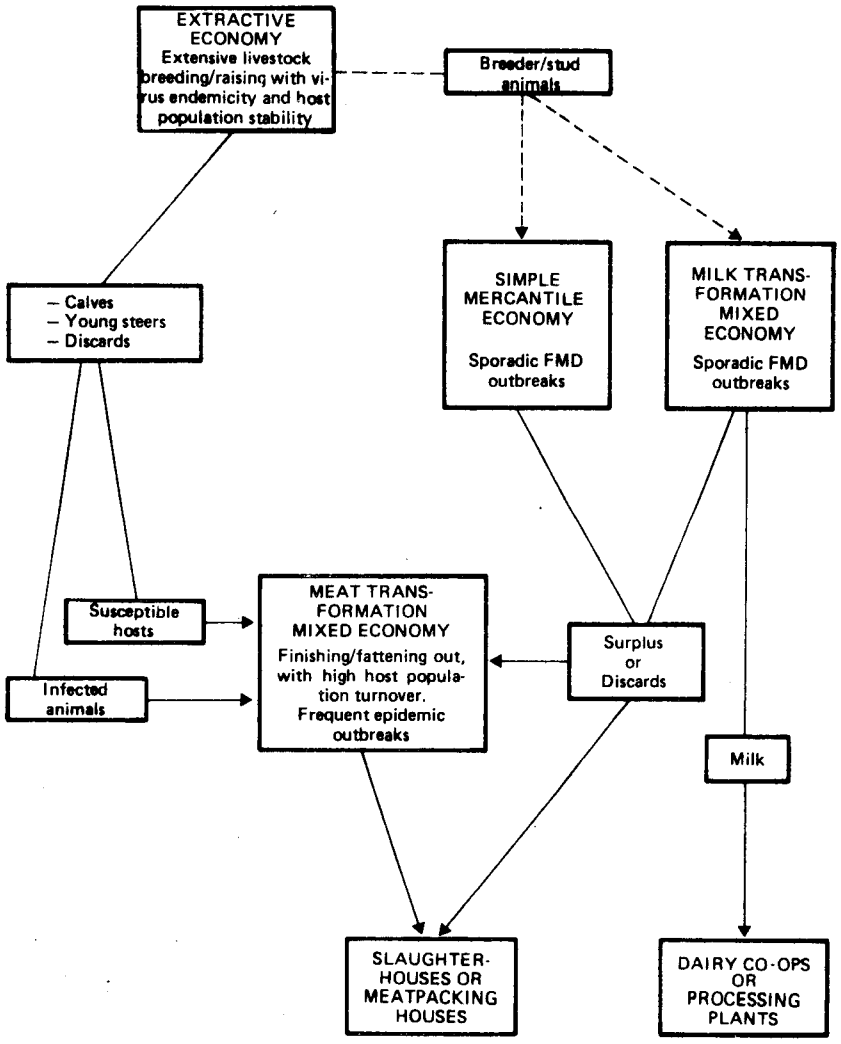

FIGURE 2. ***Relationship between the economic structures and FMD epidemiology. The transformation areas for meat production purposes show a high degree of epidemiological dependence on the primary productive structures, which they economically condition (see text).***

VI. CONCLUSIONS

The social determination of the health-disease process is being intensely analized in various public health sectors. In the communicable diseases sector Samuel Pessoa pointed out several years ago that the social structures were the principal geographic determinant of the type of agent-host interaction in human populations with respect to Chagas disease, exanthematic typhus, bubonic plague and leishmaniasis, among others (*11*). Other authors have established differences between the diseases clearly associated with man's productive relationships and those more closely related to nature. The latter would include the diseases of the domestic animals whose relationship with nature would be immediate, which is to say "not mediated by the social order" (*1*). This work indicates that the "social organization" of cattle populations (and the same applies to all the domestic species), depends almost solely on the mechanisms by which organized man appropriates them for his benefit. Hence, health programs should no longer be founded on functionalist virus-infection-disease-immunity models but rather on regional studies whose geographic and social basis determines the most adequate strategies.

It is felt that this approach will make it possible in the near future to develop socioeconomic indicators to diagnose the priority animal health problems according to the social status of the livestock related community, orient the research on communicable diseases and propose complete solutions envisioning not only the production but also the productivity, availability and distribution of food at the socialwide level.

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