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Use of Mathematical Modeling and Simulation in Animal Disease Reporting

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Abstract

Mathematical modeling and simulation play a significant role in reporting animal disease, draw designs and establishing disease control plans. Generally, mathematical models and simulation give macroscopic predictabilities of disease spread by making some realistic expectations like homogeneous and well-mixed population and also helpful to simplify the multifaceted disease spreading process. Though, these expectations and simplifications also restrict the capability of mathematical models to characterize the spread of animal disease thoroughly. Current study will discuss complete review of mathematical models to provide an understanding about use of mathematical modeling and simulation in animal disease reporting including general description about mathematical models, their types, history, benefits, reasons and importance of these models. Previously mathematical modeling and simulation has been used to overcome the outbreaks of certain animal diseases like foot and mouth disease (FMD). But there is need to conduct further research for efficient use of mathematical modeling in animal disease reporting in order to overcome disease outbreaks in future as well as to enhance the national economy of developing countries.

Keywords: *Mathematical Modeling; Simulation; Disease Reporting; Outbreak*

Introduction

Infectious disease control is a major public health concern at the international level to stop the spread of communicable diseases [1]. The increase of emerging and re-emerging communicable diseases in animals like foot and mouth disease (FMD) and contagious bovine pleuropneumonia (CBPP) needs increasing interest in infectious disease reporting and surveillance system [2]. For that reason, public health agencies at the national level are working efficiently on reporting and control of communicable diseases [3]. An effective and precise surveillance and reporting system is required at all levels to make policies for control of infectious diseases [4]. Although animal disease reporting has been executed conventionally with poor organization and maintenance in many countries including Pakistan. So, current major challenge is to improve quality of animal reporting system [5]. Due to the heterogeneity about disease and unavailability of appropriate monetary funds, establishment of standards for disease reporting and surveillance system is very difficult task. Therefore, it is necessary to develop and process the flow of information and reporting systems to draw mathematical models for animal diseases [6].

If appropriate animal disease reporting systems are not developed, then it will affect four major systems including social system, food system, production system and national economy system. First three systems are linked with the livestock sector which produce disease effects due to mortality and production losses as a result of clinical or subclinical diseases; market disruption due to fear of consumers, supply shortage, or due to limitations on international trade in livestock and livestock products; control measures including costs and benefits of measures applied by farmers, governments and industry to prevent or control disease outbreaks. In addition to effects inside the livestock sector, most important effect other than livestock sector is related to effects on the public health system, tourism and wildlife [7]. So, there is dire need to develop proper animal disease reporting systems so that mathematical models and simulations can be drawn to plan control measures for avoiding losses in case of outbreaks.

What is mathematical modeling and simulation

Mathematical models and simulation are defined as collections of variables, equations and starting values that form a cohesive demonstration of a process or behavior because members of biological communities and components of the abiotic environment possess tremendously complicated interactions [8]. Mathematical models offer the resources to create evidence-based data to control infectious diseases and are useful to understand the spread of infectious diseases [9,10]. They can be used to develop prognostic and emergency arrangements during outbreaks along with the valuation of the effectiveness and efficacy of newly planned control measures [11].

History of mathematical modeling in animal disease reporting

Mathematical equations are being used to designate constituents of animal systems from almost 100 years [12]. In 1914, first of all researchers started to predict the amount of fat, work or milk obtained from an animal by giving feed containing specific quantity of starch equivalents [13]. Major purpose to draw equations for such procedures is to add quantitative accuracy to the valuation of the expected results on the basis of predetermined information. The process was called 'simulation modeling' which can use one equation or the incorporation of many equations. The first equations used to calculate constituents of animal systems till 1960s were 'static' models that explained the condition of the system for only one variable in time. These static models were applied to define the growth of animals or animal portions and to expect the nutrient and energy necessities for various livestock species on the basis of specific live weights [14]. But with the beginning and increased use of computers in the late 1960s and 1970s, the number of equations used to draw models significantly increased and named as 'dynamic models', in which time was described clearly and results were anticipated over variable periods of time using varying repeated intervals. Animal models are being developed since last 30 years by using a combination of physical-chemical theory demonstrations and conceptual equations [15].

Reasons for developing animal models

Mathematical models are being developed due to the following two major reasons (1) to determine, how a system can be understood quantitatively and in future how we can improve this knowledge by conducting research and (2) to incorporate different parts of current information for making decisions regarding selection of research activities for its improvement or for its direct use by enterprise managers [16].

Types of mathematical models used in animal science

Mathematical models may be of various types including static or dynamic, deterministic or stochastic, empirical or Newtonian. A static model has no time variable while a dynamic model has a time variable. Dynamic systems are naturally represented as differential equations. A deterministic model gives specific predictions for various quantities without using any probability distribution. While a stochastic model uses allegory elements or distributions of probability describing the probable value of a quantity along with variation. A stochastic model reveals mostly the deficiency of knowledge of reality and can give a false visualization on actuality. Technically, it is also very difficult to handle stochastic model in a short time. The empirical model mainly describes the mechanisms present in a given system, while the Newtonian model tries to provide an explanation along with the knowledge of causation of any mechanism of a system. It is

established by identifying the system's structure and dividing it in the constituting parts and then tries to examine the behavior of whole system from the individual constituents' perspective and connections between them. Consequently, this model is analytical decline. But an empirical model is developed on the basis of observation and experiment and not necessarily based on a predetermined biological concept. It examines the experimental data and makes equation or set of equations that can be used as a mathematical model to explain the characteristic variation between them [8].

Use of mathematical modeling in animal disease outbreak

An extensive foot-and-mouth disease (FMD) epidemic occurred in Japan in 2010, in which a mathematical simulation model of FMD transmission between farms was established to determine the spread of disease in the infected area. A farm distance based transmission kernel was used in this model to estimate the efficiency of numerous control strategies. Mathematical simulation results proved that rapid culling on affected farms after diagnosis helped to decrease the spread of disease by reducing infected farms to 30% of the baseline model. While early identification scenario (14 days earlier than baseline model) resulted in a small sized epidemic by reducing 35% chance of widespread disease. In addition to these, preventive culling helped to stop the outbreak more efficiently but it required extensive resources for culling operations. A 10-km vaccination 7 days after the first identification of the disease helped to reduce epidemic to a low level, but in vaccination scenario, total number of farms that were either culled or vaccinated increased than that of the baseline model. In short, this model helped to provide useful information regarding development of appropriate control plans against FMD [17].

Conclusion

Epidemiological surveillance of infectious diseases by using animal disease reporting system is essential to develop and evaluate disease control and prevention program. Lack of appropriate disease reporting system has dangerous effects on the livestock sector as well as the economy of the country. Mathematical modeling was started to report animal diseases from almost 100 years ago. Previously mathematical models are being used to plan control measures in case of outbreaks of many animal diseases specifically for FMD outbreak in Japan. It provided efficient results to overcome the spread of disease and to prevent losses. So, it is recommended to develop efficient disease reporting system so that we can draw mathematical models and simulations to overcome the outbreaks by estimating spread of infectious diseases and ultimately by planning emergency control measures.

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