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Research Note

Modelling of Economic Losses due to Some Important Diseases in Goats in India

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Abstract

A simple mathematical model has been formulated to assess the losses due to a disease in goats in India. The losses due to important diseases in goats have been computed for a 15-year period (1991-2005) based on published reports. The rank analysis has revealed that number of incidence was maximum for PPR, followed by FMD and sheep and goat pox. These three diseases have accounted for 54 per cent of the total incidences. The maximum deaths on per year average basis for the period 1991-2005 have been due to PPR, followed by sheep and goat pox, enterotoxaemia and CCP. These four diseases have accounted for about 74 per cent of deaths. The overall order with respect to the number of incidences has been found as: PPR > FMD > sheep and goat pox > CCP > fascioliasis / distomatosis > enterotoxaemia > anthrax. The corresponding ranking order with respect to number of deaths was: PPR > sheep and goat pox > enterotoxaemia > CCP > anthrax > fascioliasis / distomatosis > FMD. The total annual average loss due to all diseases in goats has been found of Rs 264.8 lakh. The PPR disease has accounted for the maximum (34.5%) loss, followed by FMD (14.3%), sheep and goat pox (14.1%), CCP (6.4%), enterotoxaemia (6.1%), fascioliasis / distomatosis (5.0%) and anthrax (2.0%). Thus, PPR, foot and mouth disease and sheep and goat pox diseases harm goat population on a large-scale. Therefore, necessary preventive measures are required to control these diseases of goats.

Introduction

The occurrence of diseases is an important factor which influences the productivity and economy of animal farming. Goats suffer from many animal diseases; and some of these are common with other livestock species, while a few are specific to goats only. Diseases in goats result in mortality and morbidity losses, resulting in low productivity of animals. Several studies (Paliwal *et al.*, 1978; Krishna *et al.*, 1979; Chauhan *et al.*, 1982; Chatterjee and Dey, 1992) have shown that on an average 20 per cent of kids and 10 per cent of adult goats die each year. Kulkarni *et al.* (1996) had carried out epidemiological investigations on goats in nine villages of the Latur district in Maharashtra and reported that

goats of all ages were affected by PPR (*Peste des petits ruminant*). Singh *et al.* (2004) have found that PPR causes large economic losses each year due to high mortality and morbidity rates in the infected sheep and goats and outbreaks were more severe in goats than sheep. Kumar *et al.* (2003) have carried out a field level study in the Mathura district of Uttar Pradesh to estimate mortality and morbidity losses in goats in India. The effect of a disease on a goat herd can be modelled by applying an increased death rate, lower milk yield, decreased body weight, increased kidding interval, etc. The assessment of losses caused due to occurrence of a disease in goats has not been carried out in India on the basis of a mathematical model. Such an assessment is constrained not only due to lack of available parameters or data, e.g. quantifiable data on weight loss, milk loss, kidding and fertility problems, etc., but

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also due to difficulties in validation of these models. Most of the estimates on losses have taken into account only direct losses, i.e. value of animals that die due to a disease. A true estimate on losses needs to take into account a variety of factors which constitute indirect losses. In this study, a simple mathematical model has been formulated for assessment of losses due to major diseases in goats in India. The numerical assessment of losses has been carried out due to seven important goat diseases, viz. *Peste des petits ruminant* (PPR), foot and mouth disease (FMD), sheep and goat pox (S&G Pox), enterotoxaemia, contagious caprine pleuropneumonia (CCP), fascioliasis / distomatosis and anthrax, on the basis of available data and some probable estimates of parameters.

Methods and Materials

The data on the number of incidence (I) and deaths (D) in goats due to different diseases were obtained from the combined data on ovine/ caprine in *Annual Reports* of the Department of Animal Husbandry and Dairying, Ministry of Agriculture, Government of India, on proportional basis of sheep and goat population during the past 15 years (1991 – 2005). The rank analysis (Siegel and Castellan, 1988) was performed for studying the trends over the years for the number of cases, deaths and economic losses due to different diseases under study. The economic losses due to a disease in goats were enumerated as follows:

Mathematical Model

(A) Losses from Mortality

(B) Milk Losses

B_1 = Value of direct loss due to reduction in milk yield

B_2 = Cost of loss of milk due to increased inter-kidding period

B_3 = Cost of loss of milk due to increased occurrence of abortions

(C) Body Weight Losses

C_1 = Value of direct loss due to decrease in body weight

C_2 = Cost of loss of live body weight due to increased inter-kidding period

C_3 = Cost of loss of live body weight due to increased occurrence of abortions

(D) Opportunity Cost (O_c)

It is the cost on higher feeding and rearing-inputs to the surviving infected animals, cost on medicines, etc.

The total economic loss (T_L) due to occurrence of a disease in goats can be based on Equation (1) :

$$T_L = A + B_1 + B_2 + B_3 + C_1 + C_2 + C_3 + O_c \dots(1)$$

Parameter Estimation and Assumptions

Information about the effect of a disease on productivity parameters can be obtained from the surveys or experiments. In their absence, the necessary parameters can be either estimated from the secondary information such as livestock census or some probable values could be used. The following parameters were obtained from the *Livestock Census Reports* and *Basic Animal Husbandry Statistics-AHS Series 6-10* and *Annual Reports* of Department of Animal Husbandry and Dairying, Ministry of Agriculture, Government of India.

I = Number of infected animals

D = Number of animals died

P_1 = Proportion of animals in milk

Z = Annual average milk yield per milch goat, and

Y = Annual average milk yield per goat in milk

The probable values used for the different parameters are given below:

P = Average market value of animal = Rs 2000

L = Proportion of lactation lost = 15 %

W_A = Average body weight = 20 kg

B_w = Average birth weight of a kid = 2.5 kg

N_k = Average number of kids per kidding = 1.5

A = Increased abortion rate = 25%

W_L = Proportion of body weight loss = 10%

K_1 = Inter kidding period = 10 months

W = Delay in next conception = 3 months

P_M = Price of milk (per kg) = Rs 10, and

P_W = Price of live-animal weight (per kg) = Rs 40

Estimation of Losses

(A) Direct Losses from Mortality

This was worked out as the product of number of died animals (D) due to the disease and probable average cost (P) of the animal. That is, $A = D \times P$

(B) Losses in Milk Yield

(B₁) Value of Direct Loss through Reduction in Milk Yield

For the proportion of goats in milk in a year, the losses were expressed in terms of reduction in milk yield, which through the price of milk could be directly converted into monetary terms. When a goat died as a result of the disease, the adopted market value was assumed to reflect its production worth. The double counting or costing was avoided. The immediate fall in milk production in lactating goats was never gained later and therefore, constituted a significant loss. The loss due to direct decline in milk production was estimated using formula (2):

$$B_1 = (I - D) P_1 LZ P_M \quad \dots(2)$$

(B₂) Cost of Milk Loss due to Increased Inter-kidding Period

The problem of non-conception caused by a disease increases the inter-kidding period and thus lower number of animals will be in milk at any given time. As a result of non-conception or delayed conception, the milk output gets reduced. An average delay of 3 months in the next conception was assumed for all the goats affected by the disease. The loss of milk was calculated by the reduction in proportion of lactating animals in any year multiplied by the average milk yield per in-milk goat per year and by the price P_M . That is:

$$B_2 = [(12/K_1) - \{12/(K_1 + W)\}] (I - D) P_1 Y P_M \quad \dots(3)$$

(B₃) Cost of Milk Loss due to Increased Abortions

The disease can cause abortion, particularly in the late pregnancies and leads to increased inter-

kidding period, besides loss of kids. Assuming the time for abortion as 3.5 months from conception, and a delay of six months in the next conception, the inter-kidding period gets increased by 9.5 months in aborting cases, and the milk loss due to increased abortions were estimated from Equation (4):

$$B_3 = [(12/K_1) - \{12/(K_1 + 9.5 A)\}] (I - D) P_1 Y P_M \quad \dots(4)$$

(C) Estimation of Losses in Body Weight

(C₁) Value of Direct Loss due to Reduction in Body Weight

The body weight loss in non-milking goats was estimated by the formula (5):

$$C_1 = (I - D)(1 - P_1) W_L W_A P_W \quad \dots(5)$$

(C₂) Cost of Live Weight Loss due to Increased Inter-kidding Period

Reduction in the number of kids due to elongated inter-kidding period after infection with a disease caused loss in the live body weight. Such losses were estimated by the formula (6):

$$C_2 = [(12/K_1) - \{12/(K_1 + W)\}] (I - D) P_1 N_K B_W P_W \quad \dots(6)$$

(C₃) Cost of Live Weight Loss due to Increased Abortions

Reduction in the number of kids due to more abortions in goats after infection with a disease caused loss in live body weight, which was estimated by the formula (7):

$$C_3 = [(12/K_1) - \{12/(K_1 + 9.5 A)\}] (I - D) P_1 N_K B_W P_W \quad \dots(7)$$

(D) Opportunity Cost (O_C)

It included: (i) Cost on higher feeding and rearing-inputs in surviving the infected goats due to loss of weight, (ii) Loss in young stock due to longer rearing-time, (iii) Cost on permanent disability, (iv) Treatment cost, and (v) Increased cost on management. These costs were difficult to quantify where records and estimates on cost of feeding and rearing were lacking. In the absence of any suitable data in this regard,

these costs were assumed approximately as 20 per cent of the cost of animal, i.e. Rs 400 per infected surviving animal, i.e.

$$O_c = (I - D) \times 400 \quad \dots(8)$$

Results and Discussion

Incidence of Disease and Deaths

The number of incidence of diseases (I) and deaths (D) in goats in different years due to seven diseases under study have been recorded in Tables 1 and 2, respectively. On the basis of average of 15-year period (1991-2005), these diseases were found to account for 82.6 per cent incidence and 82.4 per cent deaths to total incidence (27519) and deaths (4606). The PPR accounted for the maximum incidence (32.3%) and deaths (41.5%), with case fatality rate of 21.5 per cent, followed by FMD with incidence of 17.4 per cent, deaths 1.8 per cent and case fatality rate of 1.7 per cent. In Anthrax, the incidence (1.1%) and deaths (5.0%) were less, but the case fatality rate was very high (73.6%). Enterotoxaemia also had high case fatality rate (38.4%) with incidence of 4.7 per cent and deaths 10.9 per cent. Sheep and goat pox was responsible

for 13.6 per cent incidence and 14.4 per cent deaths with 17.3 per cent case fatality rate. The CCP accounted for 6.2 per cent incidence and 6.9 per cent deaths with 18.1 per cent case fatality rate. Fascioliasis / Distomatosis had incidence of 5.8 per cent, deaths 1.9 per cent and case fatality rate of 5.4 per cent. On the basis of an epidemiological investigation carried out in the Latur district of Maharashtra, Kulkarni *et al.* (1996) had reported 64.7 per cent morbidity and 13.4 per cent mortality in goats due to PPR in nine villages. In a field survey, Kumar *et al.* (2003) have found that the mortality rates in adult goats for small, medium and large categories of goat-keeping households were 31.2 per cent, 19.9 per cent and 14.9 per cent, respectively and highest mortality was due to diarrhoea and enterotoxaemia.

The rank analysis revealed that number of incidence was maximum for PPR, followed by FMD and sheep and goat pox. These three diseases accounted for 54 per cent of the total incidences. The maximum deaths on per year average basis for the period 1991-2005 were due to PPR, followed by sheep and goat pox, enterotoxaemia and CCP. These four diseases accounted for about 74 per cent of deaths. The overall ranking in decreasing order with

Table 1. Year-wise number of incidences due to different diseases in goats

| Year | FMD | Anthrax | Sheep & goat Pox | Fascioliasis/ Distomatosis | Enterotoxaemia | PPR | CCP | Others | Total |
|------------|-------|---------|------------------|----------------------------|----------------|-------|------|--------|-------|
| 1991 | 1260 | 375 | 3189 | 0 | 149 | 0 | 4512 | 3225 | 12710 |
| 1992 | 36432 | 894 | 2805 | 5639 | 170 | 0 | 619 | 10559 | 57118 |
| 1993 | 1709 | 312 | 1197 | 2479 | 106 | 233 | 3606 | 984 | 10626 |
| 1994 | 1624 | 190 | 1915 | 2682 | 44 | 0 | 5580 | 15672 | 27707 |
| 1995 | 398 | 177 | 694 | 1941 | 1 | 2521 | 2518 | 21052 | 29302 |
| 1996 | 161 | 332 | 4597 | 2911 | 1325 | 926 | 298 | 1028 | 11578 |
| 1997 | 1508 | 515 | 2956 | 2030 | 1338 | 2354 | 1075 | 3739 | 15515 |
| 1998 | 4644 | 230 | 3997 | 2716 | 838 | 6339 | 312 | 4483 | 23559 |
| 1999 | 292 | 217 | 1027 | 1287 | 1612 | 13112 | 710 | 330 | 18587 |
| 2000 | 387 | 125 | 3138 | 711 | 903 | 2132 | 186 | 152 | 7734 |
| 2001 | 8393 | 305 | 5031 | 927 | 2904 | 23499 | 964 | 8010 | 50033 |
| 2002 | 3051 | 218 | 2299 | 491 | 911 | 4754 | 1139 | 1112 | 13975 |
| 2003 | 3673 | 348 | 4531 | 189 | 1722 | 22039 | 3223 | 110 | 35835 |
| 2004 | 335 | 182 | 5954 | 74 | 1088 | 11389 | 309 | 1237 | 20568 |
| 2005 | 9572 | 231 | 14249 | 231 | 6562 | 44048 | 1067 | 1981 | 77941 |
| Average | 4896 | 310 | 3839 | 1621 | 1312 | 8890 | 1741 | 4912 | 27519 |
| Percentage | 17.4 | 1.1 | 13.6 | 5.8 | 4.7 | 32.3 | 6.2 | 17.4 | 100 |

Table 2. Year-wise number of deaths due to different diseases in goats

| Year | FMD | Anthrax | Sheep & goat pox | Facioliasis/ Distomatosis | Entero-toxaemia | PPR | CCP | Others | Total |
|------------|-----|---------|------------------|------------------------------|-----------------|-------|------|--------|-------|
| 1991 | 17 | 356 | 909 | 0 | 39 | 0 | 2074 | 1081 | 4476 |
| 1992 | 68 | 590 | 1012 | 379 | 92 | 0 | 21 | 2610 | 4772 |
| 1993 | 13 | 250 | 65 | 136 | 90 | 147 | 218 | 255 | 1174 |
| 1994 | 63 | 149 | 287 | 19 | 22 | 0 | 797 | 4433 | 5770 |
| 1995 | 35 | 172 | 133 | 380 | 1 | 190 | 250 | 2980 | 4141 |
| 1996 | 14 | 53 | 1130 | 132 | 190 | 190 | 14 | 38 | 1761 |
| 1997 | 136 | 440 | 386 | 15 | 478 | 580 | 55 | 208 | 2298 |
| 1998 | 39 | 194 | 416 | 78 | 383 | 1947 | 63 | 144 | 3264 |
| 1999 | 49 | 125 | 232 | 99 | 847 | 2796 | 156 | 133 | 4437 |
| 2000 | 3 | 56 | 243 | 5 | 247 | 493 | 11 | 0 | 1058 |
| 2001 | 139 | 260 | 1281 | 40 | 1134 | 3665 | 197 | 167 | 6883 |
| 2002 | 89 | 195 | 410 | 0 | 158 | 917 | 164 | 7 | 1940 |
| 2003 | 253 | 207 | 968 | 0 | 938 | 4138 | 463 | 14 | 6981 |
| 2004 | 12 | 159 | 597 | 15 | 819 | 3011 | 2 | 39 | 4654 |
| 2005 | 279 | 219 | 1897 | 24 | 2114 | 10616 | 305 | 22 | 15476 |
| Average | 81 | 228 | 664 | 88 | 504 | 1913 | 319 | 809 | 4006 |
| Percentage | 1.8 | 5.0 | 14.4 | 1.9 | 10.9 | 41.5 | 6.9 | 14.6 | 100 |

Table 3. Year-wise economic losses due to different diseases in goats

(in lakh Rs)

| Year | FMD | Anthrax | Sheep & goat pox | Facioliasis/ Distomatosis | Entero-toxaemia | PPR | CCP | Others | Total |
|------------|--------|---------|------------------|------------------------------|-----------------|--------|-------|--------|--------|
| 1991 | 9.59 | 7.26 | 35.15 | 0 | 1.60 | 0 | 59.62 | 37.58 | 150.80 |
| 1992 | 272.01 | 14.06 | 33.58 | 46.73 | 2.42 | 0 | 4.87 | 111.36 | 485.04 |
| 1993 | 12.88 | 5.46 | 9.72 | 20.16 | 1.92 | 3.58 | 29.58 | 10.53 | 93.83 |
| 1994 | 12.88 | 3.28 | 17.86 | 20.20 | 0.60 | 0 | 51.54 | 172.31 | 278.67 |
| 1995 | 3.40 | 3.48 | 6.84 | 19.22 | 0.02 | 21.15 | 21.88 | 194.10 | 270.09 |
| 1996 | 1.35 | 3.10 | 47.95 | 22.96 | 12.10 | 9.18 | 2.36 | 8.00 | 106.99 |
| 1997 | 12.75 | 9.35 | 26.51 | 15.03 | 15.85 | 24.57 | 8.56 | 29.98 | 142.59 |
| 1998 | 34.45 | 4.14 | 34.50 | 20.85 | 10.99 | 71.05 | 3.08 | 34.60 | 213.66 |
| 1999 | 2.76 | 3.17 | 10.451 | 10.66 | 22.53 | 131.34 | 7.17 | 4.10 | 192.19 |
| 2000 | 2.87 | 1.62 | 26.03 | 5.26 | 9.74 | 21.84 | 1.50 | 1.11 | 69.97 |
| 2001 | 66.30 | 5.55 | 54.48 | 7.62 | 36.30 | 225.93 | 9.84 | 63.69 | 469.71 |
| 2002 | 24.57 | 4.08 | 22.74 | 3.78 | 8.95 | 47.87 | 10.78 | 8.64 | 131.41 |
| 2003 | 31.38 | 5.22 | 46.78 | 1.45 | 24.79 | 220.51 | 30.50 | 1.02 | 361.66 |
| 2004 | 2.73 | 3.36 | 53.16 | 0.75 | 18.45 | 124.69 | 2.40 | 10.00 | 215.54 |
| 2005 | 77.09 | 4.47 | 132.99 | 2.07 | 76.51 | 469.59 | 11.96 | 15.52 | 790.20 |
| Average | 37.80 | 5.17 | 37.25 | 13.12 | 16.18 | 91.42 | 17.04 | 46.84 | 264.82 |
| Percentage | 14.3 | 2.0 | 14.1 | 5.0 | 6.1 | 34.5 | 6.4 | 17.7 | 100 |

respect to the number of incidence was: PPR > FMD > sheep and goat pox > CCP > fascioliasis / distomatosis > enterotoxaemia > anthrax. The corresponding ranking order with respect to number of deaths was: PPR > sheep and goat pox > enterotoxaemia > CCP > anthrax > fascioliasis / distomatosis > FMD.

Economic Losses

The economic losses due to all diseases, estimated in terms of losses due to mortality, milk yield, body weight and opportunity cost, have been presented year-wise in Table 3. The total annual average loss due to all diseases in goats was of Rs 264.8 lakh. The annual loss was maximum in the year 2005 (Rs 790 lakh) and minimum in the year 2000 (Rs 70 lakh). The average annual economic loss was highest due to PPR (Rs 91.4 lakh), followed by FMD (Rs 37.8 lakh), sheep and goat pox (Rs 37.2 lakh), CCP (Rs 17.0 lakh), enterotoxaemia (Rs 16.2 lakh), fascioliasis / distomatosis (Rs 13.1 lakh) and anthrax (Rs 5.2 lakh). The disease-wise analysis of average losses for the 15-year period revealed that PPR accounted for maximum (34.5%) of the total disease losses, followed by FMD (14.3%), sheep and goat pox (14.1%), CCP (6.4%), enterotoxaemia (6.1%), fascioliasis / distomatosis (5.0%) and anthrax (2.0%). These diseases accounted for about 82.7 per cent of the total disease losses in goats in India. The rank analysis showed an increasing trend for total losses over the years due to all diseases in goats. The increasing trend in economic losses was noticed with PPR, sheep and goat pox and enterotoxaemia and a decreasing trend with fascioliasis / distomatosis, anthrax and CCP. The overall ranking in decreasing order with respect to total losses was PPR > FMD > sheep and goat pox > CCP > enterotoxaemia > fascioliasis / distomatosis > anthrax.

Conclusions

This study has shown an average annual economic loss of Rs 264.8 lakh due to seven diseases in goats over a 15-year period (1991-2005). The ranking of the seven important diseases in terms of their incidence, deaths and economic losses, could be scaled as: PPR > sheep and goat pox > foot and

mouth disease > enterotoxaemia > CCP > fascioliasis / distomatosis > anthrax. Thus, PPR, foot and mouth disease and sheep and goat pox are the diseases harming goat population on a large-scale. Therefore, necessary preventive measures are required to control these diseases of goats.

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