Livestock is an important sub-sector of Indian agriculture and contributes nearly 25.6% of value of output at current prices of total value of output in Agriculture, Fishing and Forestry sector. The overall contribution of livestock sector in total GDP is 4.11% at current prices during 2012–13 (DAHD&F, Government of India, 2012). In India, animal husbandry supports livelihood of more than two-thirds of the rural population. The growth of livestock sector was above 5% during 1980s but in recent decade it is below 4%. Despite deceleration, the livestock sector growth is 1.5 times larger than the crop sector indicating its importance in cushioning agricultural growth (Roop Raj and Gupta 2015). Unlike other sectors, the livestock sector ensures equity, as smallholders and landless farmers together own 75% of livestock and earn 50% income from it (Govindaraj et al. 2017). The growth of livestock sector is severely constrained by infectious and contagious diseases like foot and mouth disease (FMD).

FMD is a contagious viral disease that primarily affects cloven-hoofed animals characterized by fever and vesicular eruptions in the mouth, nose, muzzle, feet and on the mammary glands which later become erosions (Meyer and Knudsen 2001). The disease causes severe mortality and morbidity in infected farms. Earlier the mortality was recorded low but in the recent outbreaks, it was unusually high due to increase in number of exotic germplasm (Singh et al. 2008). The disease reduces productivity of animals and affects various stakeholders involved in the entire livestock sector value chain. At micro level, the primary producer is affected due to mortality, reduction in milk yield, and draught power unavailability. Further, significant amount is spent by the farmers to control the secondary bacterial infection. Some farmers resort to distress sale and may even replace the morbid animals altogether, as there will be marked decline in productivity of infected animals for a very long period. At macro level, the disease affects productivity of livestock sector and pulls down the growth of associated and interlinked sectors due to ripple effect on all the upstream and downstream stakeholders and industries (FAO 2006). In India, in order to control the disease, vaccination under Foot and Mouth Disease Control Programme (FMD-CP) was initiated during 2003–04 in 54 districts which was later expanded to 221 districts during XI plan and 640 districts during XII plan with a target to cover 316 million animals. It was also planned to establish one or more defined FMD free zones through vaccination by 2020. Since 2017–18, the control programme is being implemented in the entire country.

In India, the reported loss due to FMD was estimated based on secondary data on various time periods (Singh et al. 2013) and few studies employed primary data collected from few livestock farms (Goel 1989, Prabhu et al. 2004,
Thirunavukkarasu and Kathiraven 2006, Thirunavukkarasu and Kathiraven 2006, Litty and Deepa 2008, Ganesh Kumar 2012, Govindaraj et al. 2017). The severe drawbacks of secondary data based loss estimates are data limitation (only reported outbreaks were considered for loss calculations) and unwarranted assumptions. Similarly, the primary data based survey studies reported till date were limited to few districts and few loss parameters. Hence, to address the gap, the present study was conducted comprehensively to assess various visible losses associated with FMD, viz. milk yield reduction, draught power unavailability, treatment cost, mortality, opportunity cost of labour and distress sale. The present study was to assess the monetary impact of FMD in cattle and buffaloes in India.

MATERIALS AND METHODS

Sample size: The sample size for undertaking primary survey was determined based on Cochran (1963) formula:

\[ n = \frac{z^2 \times (P) \times (1 - P)}{c^2} \]

where, \( n \), sample size per district; \( z \), 90% confidence level (1.645); \( p \), proportion of bovine rearing households in a district in India (0.306) as per 19th livestock census 2012 and \( c \), margin of error (0.06).

The estimated sample size was 156 cattle and buffalo rearing farms per district and accordingly, the primary survey was undertaken in each of the identified sample districts with a minimum sample of 150 in each district except Puducherry. The survey was undertaken during the year 2013–14 with the pilot tested schedule developed for the purpose.

Sampling procedure: Multistage random sampling procedure was adopted for the primary survey. In the first stage, 10 states and one UT covering various geographical regions were selected. In the second stage, minimum of three districts were selected randomly in each state. In the third stage, minimum six blocks/mandals/circles/taluks were selected and in each of them a minimum two villages were selected randomly. In the fourth stage, the required number of samples to be surveyed was distributed in proportion to number of cattle and bovine rearing farms in the village. In the fifth stage, the cattle and buffalo rearing farms in each of the identified village for the primary survey were selected randomly. The total number of districts, villages and farms surveyed to assess the various loss due to FMD in various states and all India were 31, 530 and 4,822, respectively (Table 1). A farm is designated as FMD affected based on the clinical signs observed by the farmer, triangulation with the village head and corroboration with the local field veterinarian. In all the selected states minimum three districts were surveyed except Maharashtra where only two districts could be surveyed. In Puducherry (UT), one region was surveyed out of four regions.

Estimation of loss: The visible loss due to FMD, viz. milk yield reduction, unavailability of draught power, treatment cost, opportunity cost of labour, distress sale and mortality in cattle and buffaloes were estimated. The mortality loss was calculated based on number of animals that died due to FMD in each category [male and female calves (<one year), in-milk, dry, heifer, immature males (1–3 years), bullocks (>three years) and bull] in the surveyed farms multiplied by value of the animal in apparently healthy state. The milk yield loss per animal was calculated based on difference in milk yield (before disease) and actual milk yield (during the disease) in in-milk category animals and duration of FMD infection in the farm. The draught power loss was calculated based on the number of days disease persisted in the farm and bullock hiring charges per day. Treatment cost incurred by the farmer includes veterinarian fee, cost of drugs and indigenous treatment cost. The opportunity cost of labour was estimated based the incremental labour hours engaged, number of days disease persisted in the farm and prevailing labour wage rate in the survey village. The distress sale loss in the event of FMD outbreak in the farm was calculated as the difference between the market value of the animal before FMD and distress sale value of the animals realized by the farmer. Appropriate weightages were considered based on the number of animals died, infected and recovered among the various FMD infected species and age groups reared by the sample farmers for estimating the loss per animal. Based on FMD incidence, disease cost in cattle (indigenous cattle and crossbred cattle) and buffaloes, total risk population in each of the surveyed states and the loss due to FMD loss in each of the surveyed states were projected. For non-surveyed group of states, the FMD incidence level in different category of animal and disease cost per animal in the reference states and susceptible risk population in the respective state were used to calculate the total loss these were summed up total loss in these states. For Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Delhi, and Chandigarh, the disease incidence and disease cost per

| State                    | Number of district surveyed | Number of blocks/mandals/circles/taluks | Number of villages/panchayats | Farms surveyed |
|--------------------------|----------------------------|----------------------------------------|--------------------------------|----------------|
| Andhra Pradesh           | 3                          | 15                                     | 77                             | 455            |
| Assam                    | 3                          | 19                                     | 51                             | 447            |
| Gujarat                  | 3                          | 6                                      | 54                             | 500            |
| Haryana                  | 3                          | 10                                     | 46                             | 450            |
| Karnataka                | 3                          | 6                                      | 68                             | 450            |
| Kerala                   | 3                          | 6                                      | 28                             | 430            |
| Madhya Pradesh           | 3                          | 6                                      | 46                             | 451            |
| Maharashtra              | 2                          | 8                                      | 44                             | 334            |
| Puducherry               | 1                          | 7                                      | 10                             | 105            |
| Punjab                   | 4                          | 8                                      | 73                             | 750            |
| Tamil Nadu               | 3                          | 6                                      | 33                             | 450            |
| Total                    | 31                         | 97                                     | 530                            | 4822           |

Table 1. Number of districts, villages and farms surveyed in different states of India
animal estimated for Haryana was considered, whereas for Uttar Pradesh, Bihar, Jharkhand, Odisha, Chhattisgarh and West Bengal, the disease incidence level and disease cost in Madhya Pradesh was considered. For Rajasthan, Daman and Diu and Dadra and Nagar Haveli the reference state was Gujarat and for Goa and Lakshadweep, the reference states were Maharashtra and Kerala, respectively. For all the north eastern states, the reference state was Assam.

RESULTS AND DISCUSSION

The loss per animal due to FMD infection at 2013-14 prices in the surveyed farms in various states are presented in Table 2. Among the indigenous cattle, in the study states, the milk reduction loss per animal ranged from INR 427 to INR 2,700 with highest in Kerala whereas in crossbred cattle, the treatment cost per animal range from INR 246 to INR 3,068 (Table 2). The estimated mortality loss per animal in indigenous and upgraded buffalo in different surveyed states is presented in Table 2. Among the study states, considerable variation in monetary loss due to milk yield reduction was mainly due to differences in species, breed, age, lactation stage, milk yielding capacity of animals, number of days FMD persisted in the farm etc.

In general, mortality due to FMD was observed in young animals whereas during 2013–14 outbreaks mortality was observed in adult animals also in some of the states. The mortality loss ranged from INR 2,027 to INR 50,000 per animal in indigenous cattle and INR 1,912 to INR 35,920 in crossbred cattle. Similarly, the estimated mortality loss per animal in indigenous and upgraded buffalo in different surveyed states is presented in Table 2. The loss variation within species was due to difference in prices of various milch breeds reared by farmers in each of the surveyed states. Among the indigenous cattle, highest mortality loss per animal (INR 50,000) was observed in Gujarat and least in Madhya Pradesh state. The indigenous cattle breed (Gir/ Red Sindhi/Sahiwal) reared in Gujarat is highly valued over the breeds of similar age and sex reared in Madhya Pradesh like Manthani, Kenwariya etc. Further, the death of young animals resulted in less average mortality loss than old animals. Several studies revealed that mortality of young animals due to FMD were more, whereas during 2013–14 outbreaks adult animals died in large numbers in the southern states and hence, estimated mortality loss per animal varied across species (Govindaraj et al. 2017). More deaths of adult animals might be due to change of composition of species reared (more crossbreds than indigenous breeds), change in husbandry practices, free movement of animals for trade and transit across borders etc. Further, change in climatic factors might also favour the transmission and full expression of FMD virus causing heavy mortality in the susceptible host (Singh et al. 2008).

The distress sale occurs in the farm when the farmer decides to sell the infected animals at less price than its original value. The distress sale loss varied depending on the species, age, disease condition, availability of market for the infected animals etc. The estimated distress sale loss per animal at 2013–14 prices in indigenous cattle range from INR 200 to INR 11,727 with the loss being the least in Madhya Pradesh and the most in Karnataka during the study period. In crossbred animals, the distress sale loss ranged from INR 4,000 to 32,286. The distress sale estimated for indigenous and upgraded buffaloes in the surveyed states is presented in Table 2. Among the states surveyed during 2013–14, highest loss of INR 11,727, INR 32,286 and INR 21,250 in Indigenous cattle, Crossbred cattle and Indigenous buffalo was observed in Karnataka and the results corroborates with earlier study by Govindaraj et al. 2017. The distress sale affects the regular income generation from livestock and the asset structure of the farmers in the long-run.

In India, draught power from animals is an important energy source for agricultural operations like ploughing, intercultural operations, post-harvest activities etc. The estimated loss per animal ranged from INR 2,453 to INR 8,886, with highest loss in Assam, which might be due to more use of indigenous cattle in Assam for agricultural operations than in other surveyed states. The average effective working days lost ranged from 5 to 15 days in the surveyed states and similar results were reported by Jemberu et al. (2014). The treatment cost incurred by farmers to control FMD varied in different states depending on the severity of infection, disease persistency, timely treatment and veterinary infrastructure in the states. In Indigenous cattle, the treatment cost per animal range from INR 246 to INR 2,700 with highest in Kerala whereas in crossbred cattle, the cost ranged from INR 250 to INR 3,068 (Table 2). The treatment cost estimated varied from the study reported by Young et al. (2013) in Cambodia (INR 1059/USD 15.13). The differences in estimated treatment cost might be due to difference species affected, recovery period, timely availability of professionals, treatment regimen adopted etc. The cost of labour for nursing the infected animal vary depending on the number of animals in the farm, prevailing labour wages in the village and number of days of infection. The estimated incremental labour cost was least in Assam (INR 341) and highest in Kerala ranging from INR 3,375 to INR 4,500 per animal.

In general, there is variation in loss per animal between the species and between different components due to various host and management factors. In the present study, the mortality loss was highest followed by draught power and milk loss whereas Ganesh Kumar (2012) found in Andhra Pradesh that the maximum loss was on draught power reduction, followed by milk yield reduction, treatment cost and mortality and Litty and Deepa (2008) found in Kerala that the highest loss was due to milk yield reduction. The variation in loss components estimated in the present study...
Table 2. Estimated average unit cost per animal affected by FMD among the sampled farms in the surveyed states at 2013–14 prices

| Category/State     | Species       | Andhra Pradesh* | Assam | Gujarat | Haryana | Karnataka | Madhya Pradesh | Maharashtra | Puducherry | Punjab | Tamil Nadu |
|--------------------|---------------|-----------------|-------|---------|---------|-----------|----------------|-------------|------------|---------|-----------|
| Milk loss          | IC            | 2936            | 427   | 1445    | NO      | 2949      | 2940           | 2346        | 784        | NA      | NO        | 768       |
|                    | CB            | NO              | 4804  | 1145    | NO      | 5454      | 6850           | 7826        | 2659       | 1476    | NO        | 1991      |
|                    | IB            | 3617            | NO    | 2641    | 4514    | 1660      | NO             | 5684        | 1015       | NA      | NO        | 1152      |
|                    | UB            | 6058            | NO    | NO      | NO      | 1689      | NO             | 7685        | NO         | NA      | NO        | NO        |
| Draught power loss | IC            | 2625            | 8886  | 3656    | NO      | 3752      | NO             | 2453        | 6681       | NA      | NO        | NO        |
|                    | CB            | NO              | NO    | NO      | NO      | NO        | NO             | NO          | NO         | NO      | NO        | NO        |
|                    | IB            | NO              | NO    | NO      | NO      | NO        | NO             | NO          | NO         | NO      | NO        | NO        |
|                    | UB            | NO              | NO    | NO      | NO      | NO        | NO             | NO          | NO         | NO      | NO        | NO        |
| Treatment cost     | IC            | 246             | 735   | 1245    | 1750    | 1050      | 2700           | 505         | 1250       | NA      | NO        | 990       |
|                    | CB            | 250             | 1480  | 1177    | NO      | 2379      | 1965           | 3068        | 3324       | 541     | NO        | 1274      |
|                    | IB            | 366             | NO    | 982     | 2283    | 2379      | NO             | 975         | 1374       | NA      | NO        | 1138      |
|                    | UB            | 419             | NO    | NO      | NO      | 1572      | 1400           | 3150        | NO         | NA      | NO        | NO        |
| Opportunity cost of labour | IC | 1341 | 341 | 494 | 1080 | 1950 | 3375 | 611 | 1422 | NA  | NO  | 1100 |
|                    | CB            | 1341            | 341   | 494    | NO      | 1950      | 4214           | 611         | 1422       | 499     | NO        | 1100      |
|                    | IB            | 1341            | NO    | 494    | 1106    | 1950      | NO             | 611         | 1422       | NA      | NO        | 1100      |
|                    | UB            | 1341            | NO    | NO      | NO      | 1950      | 4500           | 611         | NO         | NA      | NO        | NO        |
| Mortality loss     | IC            | 13125           | 2150  | 50000   | 4000    | 26250     | NO             | 2027        | NO         | NA      | NO        | NO        |
|                    | CB            | NO              | 1912  | 16000   | NO      | 35920     | 11845          | 25459       | 22800      | 5750    | NO        | 13450     |
|                    | IB            | 9562            | NO    | 4063    | 31226   | 17885     | NO             | 8833        | NO         | NA      | NO        | 13500     |
|                    | UB            | 15968           | NO    | NO      | NO      | 25724     | NO             | 11690       | NO         | NA      | NO        | NO        |
| Distress sale loss | IC            | NO              | 3500  | 11667   | NO      | 11727     | NO             | 200         | NO         | NA      | NO        | NO        |
|                    | CB            | NO              | NO    | NO      | NO      | 32286     | 13155          | 4000        | NO         | 15667   | NO        | NO        |
|                    | IB            | NO              | NO    | 13333   | NO      | 21250     | NO             | NO          | NO         | NA      | NO        | NO        |
|                    | UB            | NO              | NO    | NO      | NO      | 28000     | 13000          | NO          | NA         | NO      | NO        | NO        |

*Undivided Andhra Pradesh; NO, FMD was not observed in the respective species during the survey; and NA, Animals of particular species were not available in the surveyed sample farms; IC, Indigenous Cattle; CB, Crossbred Cattle; IB, Indigenous Buffalo; UB, Upgraded Buffalo.
might be due to more mortality of adult animals in south states during 2013–14 FMD outbreaks. The study conducted by Senturk and Yalcin (2008) in Turkey was in line with present study that in all breeds, the highest losses occurred when animals died after FMD infection. Similarly, Jemberu et al. (2014) reported that the highest mean economic loss at the individual affected animal level was due to mortality USD 129/animal in crop-livestock mixed and USD 151/animal in pastoral system.

The disaggregated (state level) loss due to FMD in bovines in the surveyed states and other group of states is presented in Table 3. The total estimated loss due to FMD in bovines in India during 2013–14 was INR 20,897 crore with wide variation among the surveyed states. The variation in loss levels among the surveyed states were due to variation in disease incidence and severity levels, productive capacity of the animals, animal health infrastructure, population level, composition of crossbreds etc. in the respective states during the surveyed period. In future, the long-term studies need to be undertaken to capture variation in disease incidence along the disease cycle for comprehensive assessment and control of FMD in India.

The study clearly indicated that FMD caused huge visible loss to the farmers. It has ripple effect on the upstream and downstream activities of the whole livestock economy. Hence, its control is imperative mainly through preventive actions like vaccination and adopting appropriate biosecurity measures at the farm. Despite implementation of vaccination programme in some of the states, the estimated loss due to FMD in bovines was high. Hence, there is need for timely vaccination with effective vaccines to mitigate the mortality, morbidity and consequent loss to farmers and other stakeholders in the entire livestock economy in different states in India.

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