11-Livestock Integration with Agroforestry: Innovation in Technologies, Diseases and Their Control

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Abstract

Agroforestry is a recent scientific activity and modified version of social forestry aiming profitability with environmental sustainability. Animal agroforestry refers to the system of land use which consists of livestock rearing and cultivation of crops within woody plants. Animal agroforestry is economical, environment friendly and helps in enhancing both food and forage production simultaneously from the same unit of land. The important agroforestry systems with livestock are silvipastoral system (forestry + pasture + livestock), agri-silvipastoral system (agriculture + forestry + pasture + livestock) and horti-pastoral system (orchards + pasture+ livestock). Many of the infectious diseases like foot and mouth disease, peste des petits ruminants, bluetongue, sheep and goatpox, infectious bovine rhinotracheitis, bovine viral diarrhoea, haemorrhagic septicaemia, black quarter, anthrax, enterotoxemia, tuberculosis, brucellosis, paratuberculosis, mastitis have been reported in the agroforestry. Tick borne diseases like Crimean-Congo haemorrhagic fever, Kyasanur forest disease, theileriosis, babesiosis, anaplasmosis, etc poses a major constraint to animal health and productivity. Various parasitic diseases like trypanosomiasis, coccidiosis, fascioliasis, paramphistomosis, haemonchosis and toxocariasis have been reported. These infectious diseases cause economic losses due to morbidity, mortality, decreased production (milk and meat), decreased draught power and fertility. Additional economic burden happens due to cost of treatment, abortion, consequences on internal livestock movement, and ban on germplasm and international trade. Epidemiological studies suggested that occurrence and prevalence of infectious diseases in agroforestry are due to lack of regular vaccinations in practice. Important non-infectious diseases are milk fever, ketosis, post-parturient heamoglobinuria, ruminal acidosis and alkalosis, pica and downer's cow syndrome, and important phytotoxins induced poisoning are cyanogenic glycoside, mimosine, nitrate and nitrite poisoning, and photosensitization. Diseases cannot be effectively controlled without timely and accurate diagnosis. Disease management can be of three types: prevention, control and eradication. Vaccination is the practical, feasible and effective approach for the control of diseases in our country. Treatment with antibiotics can help to reduce the risk of transmission of contagious diseases. Profitability is the keyword in sustainability of any system. Agroforestry provide support and thus innovative low input technologies are essential to harvest the benefit of the system for higher profitability.

Key Words: Livestock, Agroforestry, Innovative technologies, Diseases, Control measures.

Introduction

For wider adoptability of any systems, two important aspects are profitability and sustainability in long term. This is the driving fact for researchers to optimize production/productivity and provide maximum profitability in sustainable way. This is the driving force for developing and improving farming systems.Agroforestry is a recent scientific activity and modified version of social forestry aiming profitability with sustainability. India possesses nearly 20% of the world livestock and 16.8% of the world human population with only 2.3% land area. India is first in cattle (16%) and buffalo (55%), second in goat (20%) and fourth in sheep (5%)

population in the world. Most of the forest land is owned and managed by State Forest Department (SFD). Adjacent villagers have right to use these forest lands for grazing their animals and collecting fodder and fuel as per prescribed rules and regulations of SFD. The advantages of agroforestry technologies are meeting out human and environmental needs, production of feed and fodder to livestock resulting in increased income, increased crop production and reduced labour for herding cattle, and improved soil fertility through dung of livestock, and production of leguminous and other agroforestry trees.

Animal Agroforestry

Animal agroforestry refers to the system of land use which consists of livestock rearing and cultivation of crops within woody plants. The animal agroforestry system carries various advantages. It provides excellent fodder and firewood, protects and increase soil productivity, and improves social and economic status of rural farmers by creating additional livelihood and income. The system is compatible with culture and social life of rural farmers and reduces the risk in dry land agriculture due to unpredicted climatic conditions. Further, animal agroforestry system being economical, environmentally friendly and helps in enhancing both food and forage production simultaneously from the same unit of land.

Increased demand for food and feed has lead to increased deforestation and land degradation which resulted in various consequences like ecological and environmental imbalances, soil erosion, etc. Due to reduced forest resources, availability of natural fodder for livestock became scarcity. In future, animals can no longer be fed with sufficient quantities of food grains as concentrate feed, because of constant increase in demand of food grains for human consumption. Further, there is great pressure on livestock rearing due to scarcity of feed and fodder as a result of decreased land available for fodder production.

Though, India is leading producers of milk, meat and eggs; productivity of animals is 20-60% lower when compared to the global average due to improper nutrition, inadequate health-care and management, and lack of scientific breeding of animals. Half of the total losses in livestock productivity are contributed to inadequate supply of feed and fodder.The requirement of green fodder to livestock in 2015 was 1097 million tonnes where as the available green fodder was only 400.6 million tonnes leaving a deficit of 696 million tonnes which accounts for 63.5% deficit. The requirement of dry crop residues in 2015 was 609 million tonnes where as the available dry crop residues was only 466 million tonnes leaving a deficit of 143 million tonnes which accounts for 23.56% deficit. The concentrates required during the year 2006-07 was 130.55 million tonnes, where as the availability was only 48.27 million tonnes leaving a deficit of 63.03 million tonnes which accounts for 64% deficit. At present agroforestry meets almost9-11% of the green fodder requirement for livestock, besides meeting the subsistence needs of households for food, fruit, fiber, medicine, timber, etc (Mathukia et al. 2016).

Livestock Integration with Agroforestry

Livestock is a cash crop and if production level is optimized using technological tools, agroforestry is the best system. Adoption of agroforestry practices in livestock production resulted in increased income to the farmers due to enhanced crop production, reduced labour especially for rearing of cattle and improved soil fertility through application of manure from livestock rearing. Improvement of pastureland or waste lands by an efficient and integrated land use management system with replantation or substitution of the existing vegetation with desirable species like agricultural crops, horticultural, forest tree species and livestock simultaneously in the same unit of land, resulted in increased overall production (Deb Roy and Pathak 1974). The important systems with livestock are:

1. Silvipastoral system (forestry + pasture + livestock)

2. Agrisilvipastoral system (agriculture + forestry + pasture + livestock)

3. Horti-pastoral system (orchards + pasture+ livestock)

The above mentioned systems are otherwise called as “animal agroforestry”, a generic name for all agroforestry systems that includes livestock as component.In India, the forage production potential can be enhanced by establishment of suitable silvopastoral systems in wastelands. Proper rotational grazing practices will cause little damage to tree and grass component of the silvopastoral system by browsing and grazing of goat and sheep, respectively. This will enhance the supply of nutritious fodder throughout the year for sheep and goats leads to disappearance of fodder scarcity resulted in higher production and maximum income to the farmer.Goats have more interest on consumption of trees and shrubs (ligneous) while sheep showed more interest on consumption of herbaceous plants. Usually goats showed a typical behaviour of opportunistic feeder, since in winter and summer they consume a greater quantity of ligneous species than herbaceous, while in spring they select more herbaceous species due to their high quality. In contrast, sheep have non preferential behaviour and consume more herbaceous species irrespective of season. Fencing costs could be reduced if animals are reared in agroforestry containing dense border trees.

Livestock Integration with Silvopastoral System

Silvopastoral (‘silvo’ means ‘tree’ and ‘pasture’ means ‘grasses’) systems are defined as growing of grasses and legumes in the inter spaces between forest trees for producing highly nutritious top fodder and forage, fuel wood, timber and increased land productivity, conserving plants, soil and nutrients etc. on sustainable basis on the same unit of land. Silvopastoral system provides two tier of grazing under *in situ* like during rainy season the animals prefer to graze green grasses and during dry season when there are no grasses, they consume foliage of the trees.

Protein bank is a silvopastoral system of agroforestry and a type of fodder bank, in which various high leaf protein rich trees and shrub legumes are planted on wasteland and rangelands to meet the feed and fodder requirements of livestock during the fodder deficit period in summer. Commonly used species include *Leucaena leucocephala* and *Gliricidia sepium*. About 25% of the total annual diet of livestock is composed of trees and shrubs. Tree species for dry areas are *Acacia modesta*, *A. nilotica*, *Ailanthus excelsa*, *A. lebbeck*, *L. leucocephala*, *Ziziphus mauritiana*, *Tecomella undulata*, etc. *A. nilotica* seeds contain 18.6% of crude protein (CP), whereas *L. leucocephala* seeds contain highest 30% of CP (Mathukia et al. 2016).

The comparative growth performance of sheep and goats were studied at National Research Center for Agroforestry (NRCAF), Jhansi on 15 months old silvopastoral system containing *Albizia amara* and *L. leucocephala* as tree part, and *Dichrostachys cinerea* as shrub. The understory vegetation contained perennial grasses such as *Chrysopogon fulvus* and pasture legumes like *Stylosanthes hamata* and *S. scabra*, while *Sehima - Heteropogon* as natural grassland. Goats and sheep grazed on silvopastoral system gained 28.6 and 2.1 g (head day^{-1}) body weight (BW), respectively, whereas goats grazed on natural grassland gained only 10.8 g BW. But, sheep grazed on silvopastoral system lost their weight at the rate of 27.4 g (head day^{-1}) in a total grazing period of 241 days even after supplementation of 1.5 kg (head day^{-1}) of *L. leucocephala* as top feed (Rai et al. 1994).

Grazing of lambs and kids with stocking density of 14 animals ha^{-1} on two tier (*Cenchrus ciliaris* and *A. excelsa*) and three tier (*C. ciliaris*, *D. cinerea* and *A. excelsa*) silvopastoral systems resulted in live weight gain of 20 to 22 kg with average daily gain of 56-61 g and 93-102 g (head day^{-1}) in lambs and kids, respectively. Silvopastoral system with rotational grazing was sufficient to provide nutrition to ewes during pregnancy and lactation (Sankhyan et al. 1997). Sheep (9 ewes and 1 ram) and goat (9 doe and 1 buck) grazed on 2 ha of silvopastoral system consisting of *L. leucocephala* as a tree component and *D. cinerea* as shrub along with natural vegetation resulted in increased lambing and kidding percentage (6 lambs and 12 kids) within 1 year and daily weight gain of 72.04 and 104.29 g $head^{-1}$ was also observed in newborn kids and lambs, respectively (Ramana et al. 2000).

Livestock Integration with Hortipastoral System

Hortipastoral systems are defined as growing of grasses and legumes in the inter spaces between fruit tree species. Only during dormant season of the fruit tree, livestock were allowed to graze on the available pasture for a period of 3-4 months in a year. Translation of orchards (mango and sweet orange) over 5 years old into hortipastoral systems with boundary plantation of *L. leucocephala* for small ruminant production would provide additional income to the farmers. Tree leaves could serve as supplementary source of proteins, minerals and trace elements for dairy cows and small ruminants.

Performance of Nellore Zodpi ram lambs were evaluated under hortipastoral systems (mango and sweet orange orchards above 5 years old with *C. ciliaris*, *S. hamata* and *C. ciliaris* + *S. hamata* established pastures and boundary plantation of *L. leucocephala*) in rainfed areas (Ramana et al. 2011). Lambs grazed on established pasture or supplemented with *L. leucocephala* foliage in addition to grazing on natural pasture significantly ($P < 0.01$) gained higher live BW than grazed alone on natural pasture. Enhanced digestibility of the feed and availability of good quality foliage and forage from the established pastures compared to natural under orchards is responsible for increased BW gain. Supplementation of plant protein sources containing medium to high CP levels will reduce CP deficiency of fibrous feeds, decrease feed retention time, improve feed intake ultimately leads to enhanced productivity in sheep. Significantly higher average daily gain (ADG) was reported with complementary grazing on *S. hamata* alone, and *C. ciliaris* and *S. hamata* forage in addition to grazing on natural pasture (Ramana et al. 2011). This could be due to relatively high content of nitrogen and carbohydrate fractions with slow-rate of degradation of *S. hamata* forage (source: www.crida.in/DRM1-Winter%20School/DBVR.pdf).

Livestock Integration with Agrisilvopastoral System

Agrisilvopastoral systems are defined as growing of agricultural crops, forest tree species and grass together on the same land, which provides food to the farmer, and feed and fodder to the livestock. During cropping seasons the animals were fed with stored straw (hay) and supplemented with grass and foliage of the trees. This system has been classified into two subgroups known as home gardens and woody hedgerows. Home gardens are one of the oldest agroforestry practices, found extensively in high rainfall areas in the states of Kerala and Tamilnadu with humid tropical climates and where coconut is the main crop. Most of the home gardens will support rearing of livestock (cow, buffalo, bullock, goat, sheep and pig) and birds (chicken and duck). Fodder and legumes can be widely grown to meet the daily fodder requirements of cattle. The waste materials from crops and homes are used as fodder $feed^{-1}$for animals or birds and barn wastes are used as manure for crops.

Diseases of Livestock in Agroforestry

A. Important infectious diseases

Many of the infectious diseases like foot-and-mouth disease, peste des petits ruminants, bluetongue, sheep and goatpox, infectious bovine rhinotracheitis, bovine viral diarrhoea, haemorrhagic septicaemia, black quarter, anthrax, enterotoxemia, tuberculosis, brucellosis and paratuberculosis (Johne's disease) have been documented in the agroforestry. These infectious diseases causeeconomic losses due to morbidity, mortality, decreased production (milk and meat), decreased draught power and fertility. Additional economic burden happens due to cost of treatment, abortion, consequences on internal livestock movement, and ban on germplasm and international trade. Epidemiological studies suggested that occurrence and prevalence of infectious diseases in agroforestry are due to no regular vaccinations in practice.

1. Important viral diseases

Foot-and-mouth disease

Foot-and-mouth disease (FMD) is endemic in India due to contagious nature of disease, unrestricted animal movement, incomplete vaccinations and in apparent infection in small ruminants which act as reservoirs. FMD causes huge economic losses due to high morbidity, international trade restrictions, massive expenditure for FMD control programmes, treatment cost and decreased productivity and draught power. It has been estimated that FMD causes direct losses of Rs. 2 00 000 millions annum^{-1}. Among 7 serotypes (O, A, C, Asia-1, SAT-1, SAT-2 and SAT-3), only O, A, C and Asia-1 were reported in India. Since 1995, C serotype has not been reported from India. About 70-80% of FMD outbreaks are due to serotype 'O' followed by Asia-1 (3-10%) and serotype A (3-6.5%) (Biswal et al.2012). FMD incidence is more during pre-monsoon and winter seasons; however incidence of FMD were reported regularly during all the months of the year. FMDV is epitheliotropic virus and multiplies in epithelial cells results in vesicle formation and inflammatory reaction. The clinical signs include high fever, vesicles in the lightly haired parts like udder and teat, mouth, feet and rupture of vesicles leaving ulcers resulted in animal refused to take feed and water. Affected animal produces smacking noise and drooling of saliva. Vesicles on the cleft of feet resulted in lameness. The post-mortem (PM) lesions in calves include grayish streaks in the ventricular musculature giving the heart a tigroid appearance due to necrosis of muscle and intense infiltration of lymphocytes. Haemorrhages and diffuse oedema in the mucosa of abomasum and small intestine may be observed. In India, FMD control programme (FMDCP) was executed in 54 districts from 8 states during 10th five year plan covering the population of 30 million cattle and buffalos. The tissue culture inactivated vaccine containing serotypes O, A, C and Asia-1, adsorbed on aluminium hydroxide and saponin added as an adjuvant is commonly used.

Peste-des-petits-ruminants

Peste-des-petits-ruminants (PPR) is a highly contagious, acute and transboundary viral disease of goat and sheep caused by the genus *Morbillivirus* belonging to the family *Paramyxoviridae*. Clinically, the disease is characterized by conjunctivitis, high fever, oculonasal discharge, necrotizing and erosive stomatitis, enteritis and bronchopneumonia followed by either mortality or recovery from the disease (Munir et al. 2013). The disease was first observed in Tamilnadu in 1987 (Shaila et al. 1989) and outbreaks are most commonly reported during the months of April to October followed by winter. Goats are more susceptible to PPR and manifest severe clinical form of disease than sheep. Several PPR outbreaks were encountered and the disease is enzootic in most of the southern states of India like Karnataka, Andhra Pradesh and Tamilnadu; western states of India like Maharashtra; eastern states of India like West Bengal and Orissa; northern states of India like Rajasthan and Himachal Pradesh; central states of India like Madhya Pradesh (Balamurugan et al. 2012). The expected annual loss due to PPR may reach up to 1800 million rupees. In northern region of India, outbreaks were most frequent in goats whereas in southern regions of India, outbreaks were most frequent in sheep (Balamurugan et al. 2012). The economic losses in sheep and goats range between Rs. 523 to 945animal^{-1} (Awase et al. 2013). The growth of goat industry is hampered by PPR owing to high morbidity (50-90%) and mortality (50-85%) rates. Kids more than 4 months and less than one year of age are more susceptible to PPR. PM lesions include erosion, necrosis and ulceration on the oral mucosa, pharynx, upper oesophagus, abomasums and small intestine. Haemorrhage and ulcers were found in the ileo-caecal junction, colon and rectum forming Zebra stripes. Mucopurulent exudates are found in the nasal opening, congestion and oedema of lungs, and pneumonia. In secondary bacterial infections, fibrinous bronchopneumonia and pleuritis is common.PPR can be controlled by effective vaccination measures and infected animals should be kept in quarantine for the period of one month. In the infected areas, movement of the animals should be restricted strictly. The NCP-PPR control scheme was implemented in 2010 and presently extended to all the states of the country.

Bluetongue

Bluetongue (BT) is endemic disease in India and the first case of BT was reported from Maharashtra during 1964 (Sapre 1964). Bluetongue virus (BTV) is a segmented RNA virus and belongs to the genus *Orbivirus* of the family *Reoviridae*. Based on serological survey, BTV antibodies had been demonstrated from Indian cattle, buffalos, goats, camels and wild ruminants. However, in cattle and buffalos, clinical form of BT has not been reported. The clinical signs vary from asymptomatic to fatal form which is determined by the BTV serotype, animal species, breed and age (Maclachlan et al. 2009). Recently, 27 serotypes have been identified worldwide with the addition of 2 more new serotypes (Ayanur et al. 2016). In India, 22 serotypes have been recognised on the basis of virus isolation and/or serology. Presently, 13 serotypes namely, BTV-1, 2, 3, 4, 6, 9, 10, 12, 15, 16, 17, 18, 21 and 23 were isolated from India especially from southern states (Rao et al. 2016). *Culicoides* spp. is the major vector for BTV. The clinical signs include high fever with reddening of nasal and oral mucosa, dyspnoea and salivation. Watery discharge from the nostrils, which later becomes mucous, dried and form crusts. Oedema of lips, nose and facegive the sheep a 'monkey-face' appearance.Tongue became bluish or cyanotic (so called bluetongue), oedematous and swollen. Haemorrhage at the junction of skin and hoof (coronet) resulted in lameness. PM lesions are oedema of lips, nose, ear and inter mandibular space.Petechial haemorrhages appear on the oral and nasal mucosa.Pneumonia and serosanguineous fluid in the pericardial sac, and pathognomonic lesion is haemorrhages at the base of the pulmonary artery and aorta. For successful control of BT in India, vector and sentinel control measures and rapid disease diagnosis are required. Vaccination of animals with an inactivated pentavalent vaccine containing BTV-1, 2, 10, 16 and 23 should be done (Reddy et al. 2010). Control of BT in India is a difficult task due to more susceptible host species and numerous BTV serotypes. Control of vector can be done by using insecticides, but it is expensive and does not provide complete relief from the vector.

2. Important bacterial diseases

Paratuberculosis (or) Johne's disease

Johne's disease (JD) is infectious, chronic wasting and granulomatous disease of cattle and buffaloes caused by *Mycobacterium avium* subspecies *paratuberculosis* (MAP). The disease characterized by weight loss and profuse diarrhea. JD mainly affects domestic and wild ruminants and poses serious economic losses to the dairy industry. JD is endemic in India and most of the time, the disease unnoticed due to chronic nature and unfamiliar symptoms to the clinicians and farmers (Tripathi 2008). It is a zoonotic disease and causes Crohn's disease (CD) in humans (Greenstein 2003). CD is a non-specific chronic inflammatory condition of the gastrointestinal tract and clinical signs are reduced appetite, bloody diarrhoea, abdominal pain, vomiting, tiredness and weight loss. Animals are often infected during early life by fecal-oral route. High seroprevalence of JD, 29.8% in cattle and 28.6% in buffalo has been reported in domestic animals from North India (Tripathi 2008). In spite of very high morbidity rates and lower productivity, economic losses in production go unnoticed in India due to chronicity. The PM lesions are emaciated carcass with gelatinous fat. Terminal part of the ileal wall is thickened and oedematous. The mucosa is folded and showed transverse corrugation or rugae, like cerebral convolution. While stretching the intestinal wall, corrugations do not disappear. In sheep and goats, corrugation is not marked.Management and control of JD are difficult due to the absence of rapid and sensitive diagnostic test for diagnosis of infected animals before clinical signs develop. JD is not curable and Johnin test positive animals should be culled from the farm as it may infect other healthy animals.

Black quarter

Black quarter (BQ) is an acute and highly fatal bacterial disease caused by *Clostridium chauvoei* affecting cattle, buffaloes, sheep and goats. The disease is characterized by high fever (107-108°F), emphysematous swelling of heavy muscles in loin, shoulders, chest and neck. While pressing the swelling, crackling sound is heard due to gas accumulation. Buffaloes usually suffer from a milder form of disease. Young cattle and buffaloes with 6 to 24 months of age and good body condition are highly susceptible. *C. chauvoei* is normally present in the intestine of animals. In the soil, spores remain viable for many years and can act as source of infection to animals. BQ is a soil-borne infection and outbreaks occur most commonly during the rainy season, in areas where moderate rainfall and dry-crop cultivation is practised. The disease is widely prevalent in Karnataka, Andhra Pradesh, Tamil Nadu and Maharashtra states of India. The PM lesions are rubber sponge and dark brown or black serosanguineous fluid exudes with gas bubbles from the affected muscles. Centre area of muscle is dry and have odour of rancid butter.Vaccination should be done for all animals which are 6 months and above, annually before the onset of monsoon in endemic areas. Burning the upper layer of soil with straw to eliminate the spores may help in endemic areas and sprinkle the lime over the carcass at the time of burial. Combined prophylactic vaccine consists of FMD and formalin inactivated cultures of *C. chauvoei* and *P. multocida*, and aluminium hydroxide adsorbed gives protective immunity. Prior to operation in ruminants, proper disinfection of surgical instruments is necessary to avoid the disease.

Haemorrhagic septicaemia

Haemorrhagic septicaemia (HS) is an acute, fatal and bacterial septicemic disease of cattle and buffaloes caused by *Pasteurella multocida*. HS is endemic in India and the disease is more severe in buffaloes than cattle. Young animals showed more severe form of disease than older animals. *P. multocida* causes HS in cattle and buffaloes, and pneumonic pasteurellosis in sheep and goats. The most prevalent serotypes in India are B:2, A:1, A:1,3, A:3, A:4, A:3,4,12, F:3, D:1, D:3, F:1, F:4 and F:4, 12. The occurrence of the disease in goats was 62%, sheep 102% and in pigs 5% has been reported during 2007-2010 in India. An estimated economic loss due to HS in India is Rs. 52550millions (Singh et al. 2008). The economic loss due to HS is Rs. 6816 per infected cattle and Rs. 10901 per buffalo. About 80.3% economic losses are due to direct effects of HS and 19.7% economic losses are due to indirect effects. In India, HS is the leading cause of mortality and second most commonly encountered disease during 1991 to 2010 (Dutta et al. 1990). The organism enters into the systemic circulation, proliferate and spread to various organs due to its septicaemic nature, produces petechial and ecchymotic hemorrhages on serous and mucous membranes in different organs. The clinical signs include high fever, dullness, dyspnoea and hot painful swelling with inflammatory exudate in the subcutaneous tissues of head, dewlap and neck.The PM lesions are swollen and haemorrhagic lymph nodes, and severely congested gastrointestinal tract mixed with blood. Vaccination with oil adjuvant and alum-precipitated vaccine should be done for the control of disease especially 2 to 3 months before the high-risk monsoon season. Good sanitary measures, quarantine, isolation of infected animals, immediate antibiotics treatment, deep burial or incineration of carcasses and restriction of animal movements to disease-free areas are essential for control of disease.

Bovine tuberculosis

Bovine tuberculosis (bTB) is a chronic bacterial zoonotic disease and easily spread to humans through inhalation of aerosols or ingestion of unpasteurized infected milk. Tuberculosis is caused by *Mycobacterium tuberculosis* complex (MTC), which has four species namely, *M. tuberculosis*, *M. bovis*, *M. africanum* and *M. microti*. *M. tuberculosis* mainly affects humans, whereas *M. bovis* causes bovine tuberculosis and affects wide host range including domestic as well as wild animals (Verma et al. 2014). The bTB is widely prevalent and causes 10-25% loss in productivity. In developing countries, there is increased incidence of *M. bovis* infection in humans causing serious public health problem due to the sharing of same habitat in domesticated animals and humans. Organisms are excreted in exhaled air, sputum, faeces, urine, milk, vaginal and uterine discharges, and discharges from open peripheral lymph nodes (Verma et al. 2014). An overall prevalence of bTB in India is 14.31 to 34.42% (Thakur et al. 2010). *M. bovis* mainly causes extra-pulmonary lesions and major route of transmission is oral route. Bovine tuberculosis has been classified as list B disease by OIE due to various socio-economic and public health concerns at the national level as well as the international trade of livestock and their products. The PM lesions are encapsulated, caseous and gritty tubercle nodules in lungs and mammary gland. Serous membranes like pleura and peritoneum, the tubercles nodules are like bunch of grapes called as pearly disease .In the early stage of infection, test and segregation are recommended while in the terminal stage of infection, test and slaughter is to be followed. However in India, it is difficult to follow due to various social and economic constraints and the existence of more wildlife reservoir. Hence, it is difficult to eradicate bTB infection from livestock until transmission between wildlife and domestic animals has prevented. The main diagnostic test used for screening of bovine tuberculosis is the tuberculin test (Baqir et al. 2014). Pasteurization of milk before marketing and organized abattoirs with carcasses can be routinely tested for TB.

Enterotoxemia

Enterotoxemia (ET) is an acute fatal disease of ruminants caused by *Clostridium perfringens* types B, C and D, produces epsilon toxin, which is responsible for lethal ET. ET is also known as pulpy kidney or overeating disease and affects cattle, sheep and goats. Sheep and goats of all the age groups are affected; however, younger animals are more susceptible to disease. Normally, bacteria are present in lower numbers in the intestine, when there is sudden change in the food or environment, the disease exacerbates. Excessive growth of *C. perfringens* occurs due to over consumption of milk or large amounts of grain, immunosuppression, heavy gastrointestinal parasitism, ration rich in carbohydrates and low in roughage, and reduced gastrointestinal motility. High carbohydrate feeding with climatic stresses may result in partial anaerobic conditions which favours the growth of all anaerobes including *Clostridial* spp. In India, every year during monsoon season, frequent outbreaks of enterotoxaemia in sheep were reported, in spite of regular vaccination against *C. perfringens* type D (Kumar et al. 2014). Most of the disease outbreaks were reported from AP, Tamilnadu, Karnataka, Maharashtra and Jammu and Kashmir. Severe enteritis and sudden death in lambs are caused by type B and C infections. The clinical signs in sheep include colic, diarrhoea and neurological symptoms. Post-mortem lesions are widespread vascular congestion with cerebral, cardiac, pulmonary and renal oedema. The infected animals should not be vaccinated, because it will flare up the disease outbreak. The vaccination strategy for young animals includes primary dose at 4 weeks of age and booster vaccination at 1 month after primary dose and all the adult animals should be vaccinated yearly once. Recently, for sheep combined aluminum hydroxide adjuvanted epsilon toxoid (recombinant) and live attenuated freeze-dried sheep pox vaccine is being used for control of ET (Chandran et al. 2010).

Anthrax

Anthrax is a highly fatal and acute febrile disease, enlisted in top five diseases of zoonotic importance in India. Cattle and sheep are highly susceptible to anthrax followed by horse, mules and pig. It is a soil-borne infection, caused by *Bacillus anthracis* and outbreaks generally occur after climatic change. The disease is enzootic in India especially Karnataka, Tamilnadu, Andhra Pradesh, West Bengal, Orissa, Maharashtra, and Jammu and Kashmir (Gunaseelan et al. 2011). The alkaline pH in soil and dry period provides the microenvironment for spore survivaland result in frequent outbreaks called as "incubator zones". Important source for spread of infection is bone meal, which is an essential feed additive. Incubation period for anthrax is 1 to 14 days. Ingested bacilli proliferate in the tonsils and subsequently reach to lymph nodes. The organisms are not killed by neutrophils due to the presence of capsule, which is resistant to phagocytosis. The capsule also has fibrinolytic activity,which prevents clotting of blood. The bacterial toxin injures the endothelium results in hemorrhages. Death may take place without symptoms in peracute form and discharge of dark tarry blood from the natural orifices. In acute form of disease fever, excitement, weakness, cyanosis, dyspnoea and subcutaneous oedematous swelling were noticed. Anthraxinfected carcass should not be opened for postmortem examination. The gross lesions are oedema and haemorrhages may be seen throughout the body, especially in serous membranes. The spleen is greatly enlarged and engorged with dark unclotted blood. Lymph nodes are swollen, oedematous and occasionally haemorrhagic. Haemorrhages and swelling may occur in the intestinal tract, liver and kidney. The important tools for the prevention of anthrax are vaccination, avoiding opening of the carcass, proper carcass disposal, burning of the bush, appropriate treatment, and in order to avert a future outbreak, annual revaccination is necessary in the outbreak areas for at least three years.

Tetanus

Tetanus is an acute, infectious and fatal toxaemic disease caused by *Clostridium tetani*, produces neurotoxin tetanospasmin, which is responsible for disease. *C. tetani* is a Gram-positive and spore-forming bacterium that grows under anaerobic conditions in necrotic tissue. The spores or bacteria are normally found in the soil and the gut of animals and humans, and excreted in the faeces and contaminate the soil or pasture. The spores persist in the soil for years and are resistant to most common disinfectants. Portal of entry for spores is through deep punctured wound including surgical wound, calving and castration, and through umbilicus. Sheep and goats are more susceptible than cattle. In India, only sporadic cases of disease have been reported. The disease is characterized by hyperesthesia (increased sensitization), generalized rigidity, tetany (localized spasmodic contraction), muscle stiffness, trismus (lockjaw), convulsion,prolapse of third eyelid, erection of ear and typical "pump-handle" position of tail. Antibiotic treatment with penicillin G procaine in high dose at 30,000 IU kg BW^{-1} twice daily, intramuscularly is effective to certain extent. Administration of tetanus antitoxin before clinical signs appear is effective;however, it is of limited value once clinical signs have appeared.Supportive therapy like muscle relaxant chlorpromazine (1 mgkg BW^{-1}) administered intramuscularly, thrice a day to control muscle spasms. Vaccination is usually not practiced in ruminants but in areas where cases may be anticipated, administer 0.5 ml for small ruminants and 1 ml for large ruminants, intramuscularly and administer a booster dose 4 to 8 weeks after the first dose and revaccination should be done annually.

Brucellosis

Brucellosis is one of the most important zoonotic bacterial diseases in the world. It is a disease of animals with humans as an accidental host (Joshi and Parkash 1971). Brucella is a Gram-negative facultative intracellular bacteria and bovine brucellosis is caused by *B. abortus*, less frequently by *B. melitensis* and rarely by *B. suis*. The disease is characterized by loss of milk production, abortion, birth of weak or diseased calf, repeat breeding and even mastitis. Abortion occurs typically after 5^{th} month of pregnancy. The disease is highly endemic in different states of the country and reported in different animal species like cattle, buffalo, sheep, goats, camel, yak and pig (Smits and Kadri 2005). But, the highest prevalence is seen in dairy cattle. There are various reasons of its endemicity viz. ignorance of carrier animals, ineffective test and slaughter policy in most of the Indian states, improper and unplanned vaccination, no effective quarantine and uncontrolled trans-state migration of animals.In India, on an average, the disease causes revenue losses of Rs. 420 per cattle, 1100 per buffalo, 42 per sheep, 30 per goat and 36 per pig with the total economic loss of Rs. 350 million. The prevalence of disease was 8.85% in goats and 6.23% in sheep in India (Hemadri and Hiremath 2011).

Control and management of animal brucellosis include careful herd management, hygiene and vaccination. Many countries attained brucella free status by employing test and slaughter policy. However, in India, only "test and segregation" policy is practically adaptable to control the disease. Vaccination is the practical, feasible and effective approach for the control of brucellosis in our country. Hygienic disposal of uterine discharges, foetus, foetal membranes is required. Increased public awareness through health education programmes is necessary. Vaccination with *B. abortus* strain 19 vaccine is in use for female cattle and buffalo calves between 4 to 6 months of age followed by annual revaccination and all adult females just after parturition. The vaccine should not be administered to pregnant animals, bulls and male calves (Hemadri and Hiremath 2011). Disinfect the lochial discharges daily in the animal shed with 1-2% NaOH or 5% sodium hypochlorite (bleach) solution till the discharges cease (usually for 10 –15 days).

3. <u>Important parasitic or helminthic diseases</u>

Arid climate is not very conducive for some of the parasitic infestations like fascioliasis and cestodiasis. However, increased availability of water for irrigation and the animals husbandry practice being either migratory or of intensive type leads to hitherto unreported type of parasitism in animals (Mbati et al. 2002). On the other hand, hot and humid climates are very conducive for all types of parasitic diseases. Endoparasites usually live inside the digestive tract, lungs, nasal passage, eye etc. of the host, feeding on tissue fluids or blood of the animal and causing disease in both animals and humans. Eggs are passed through the faeces which contaminate the pasture, feed or water sources. There are four types of worms namely flukes which are found in the rumen and liver, schistosomes are found inside the blood vessels, tapeworms are found in the digestive tract and round worms are found in various orgnas. Different treatment regimens are required based on the type of the worm. Common symptoms of worm infections are diarrheoa, sub-mandibular oedema (bottle-jaw), delayed age at maturity, reduction in growth rate and milk production, lower reproductive, draft and feed conversion efficiencies, lower disease resistance, anaemia, jaundice, cough (lungworm) etc. Thick nasal discharge, snoring and shortness of breath may be seen in nasal schistosomiasis infection.

Fascioliasis

Fascioliasis is caused by *Fasciola gigantica* and *F. hepatica*. In India, fascioliasis is more commonly caused by *F. gigantica*. The disease is more common in sheep and buffaloes, and causes high economic loses. *Lymnaea acuminate* has been identified as intermediate host. Livestock of Terai region is having the maximum incidence of fasciolosis when compared to hills and plains (Garg et al. 2009). In cattle and buffaloes, high prevalence of disease was noticed during winter months followed by summer and rainy season. However, in sheep and goats, high prevalence of disease was noticed during rainy season. The clinical signs are sub mandibular oedema due to hypoproteinaemia or loss of absorption of proteins by the host. Acute form of fasciolosis is caused by immature flukes and it is a less common form when compared to chronic form. In tropical climate, the *Lymnaea* snail population in pastures, around water loggings and ponds increases from June onward. Animals pick up infection while grazing and parasite matures in 9-12 weeks of infection. Thus, animal infected in June-July starts voiding ova by September-October. Ova are ingested by snails and cercariae development starts. The metacercariae are available within 1 to 1.5 months in the pasture and ready to be ingested with grasses. Acute form is characterized by traumatic hepatitis, extensive destruction of liver parenchyma with haemorrhage due to the migration of immature flukes. Sub acute form is common in animals of all ages. A complication of acute fasciolosis is occurrence of black's disease caused by *Clostridium novyi* due to the anaerobic lesions caused by immature trematodes. Chronic fasciolosis is due to adult flukes and characterised by hepatic fibrosis. Most common form and seen in sheep, cattle and other ruminants. Thickening of bile duct wall epithelium due to presence of adult flukes, giving the appearance of pipe stem liver or clay pipe cirrhosis. The effective method for disease control is control of snail population using molluscide ($CuSO_4.7H_2O$). Some of the plants like *Alstonia scholaris*, *Thevetia peruviana*, *Euphorbia pulcherima* and *Euphorbia hirta* act as snailicide.Treatmentincludes oxyclozanide (15-20 mg kg BW^{-1}, orally) and diamphenithide (ideal drug). Triclabendazole (10 mg kg BW^{-1}) is considered as the drug of choice for fasciolosis since it was found to be effective against both immature and adult flukes.

Paramphistomosis

Among the parasitic diseases, paramphistomosis is one of the most pathogenic diseases in domestic animals causing heavy economic losses to the livestock industry. Paramphistomosis is a group of disease caused by various species of parasites and all the species are not pathogenic. Several clinical outbreaks proved that the predominant species in domestic ruminants are *Paramphistomum epiclitum*, *P. cervi*, *Gastrothylax crumenifer*, *Gigantocotyle explanatum*, *Cotylophoron cotylophorum* and *Fischoederius elongatus*. The other amphistome species found in sheep are *Cotylophoron bareilliensis* and *C. indicum*, in goats*C. bareilliensis* and in buffaloes *P. dutti*, *Duttiela cephaloporus*, *Olveria bosi* and *O. indica* (Prasad and Varma 1999). The disease is a major concern in low-lying areas as the intermediate host snail population viz. *Indoplanorbis exustus* and *Gyraulus convexiusculus* increases mainly during monsoon and post monsoon season (Hassan et al.2005). The disease is widely prevalent in India resulting in heavy losses in terms of mortality, morbidity, reduced wool, meat and milk production, reproductive disorders and expenditure on the purchase of antiparasitic drugs. Mature parasites are predominantly found in the dorsal and ventral sacs of rumen of buffaloes, sheep and goats (Varma et al.1989). The immature flukes are plug feeders and found in the duodenal mucosa causing severe enteritis, duodenitis and haemorrhages, resulting into anaemia, hypoproteinemia, edema, decreased weight gain and production (Soulsby 1982). In the Indian subcontinent, immature paramphistomosis ranks next to fasciolosis and the mortality can reach up to 30% in cattle, and 80 to 90% in sheep and goats (Agrawal 2003). Clinical signs in infected animals are anorexia, polydipsia, unthriftiness, emaciation and foetid foul smelling diarrhea along with immature flukes in the faces. The animals also show bottle jaw which is characteristic of fluke infection. Death may occur within 15-20 days after the onset of clinical symptoms. The immature amphistomiasis is also called as ‘gillor’ or ‘pitto’ in Hindi. PM lesions are pale mucous membrane, gelatinous subcutaneous fat, hydrothorax, hydropericardium and Hemorrhagic duodenitis. The immature flukes can be seen as pink colour clusters attached in the duodenal mucosa. Diagnosis is based on clinical signs, faecal examination, immature flukes in diahorrheal feaces and presence of snail in grazing areas. Presence of eggs in the faeces only indicates the presence of adult flukes and has no diagnostic value for an outbreak of the acute disease caused by immature amphistomes. Treatment includes oxyclozanide (15-20 mg kg BW^{-1}, orally, 3-5 days), niclofolon (6 mg kg BW^{-1}), bithionol (40 mg kg BW^{-1}) and niclosamide (90 mg kg BW^{-1}). As amphistomiasis usually occurs along with GI nematode infection, a combination of oxyclozanide with tetramisole should be given to sheep and goats. Control measures include control of snail and proper drainage of water from lakes and ponds.

Haemonchosis

Haemonchus contortus is also known as twisted stomach worm or barber pole worm. *H. contortus* is a most pathogenic blood-sucking gastrointestinal nematode found in the abomasum of small ruminants and *H. placei* usually affects cattle. The disease causes significant economic losses due to insidious loss of production, weight loss and high mortality in lambs (Saminathan et al. 2015). *H. contortus* is important emerging anthelmintic resistance parasite. These parasites are more prevalent in the tropical and warmer temperate countries, especially where there is good rainfall in the summer season. The acute and debilitating form of disease is most commonly seen in young animals while adult animals are resistant to infection. The adult worms and fourth stage (L4) larvae are the vigorous blood-suckers, movement of the worm causes wounds and secretion of anti-coagulants causes continuous haemorrhage from the abomasal wall results in severe anemia and reduced productivity (Saminathan et al. 2015). *H. contortus* life cycle is direct and infection of definitive host is by ingestion of infective stage along with herbage. Following ingestion, exsheathment occurs in rumen, then L3 migrate to abomasum and penetrate between the gastric epithelial cells, where L3 to L5 moulting occurs. Finally, L5 comes to the surface of abomasum and reach maturity. Prepatent period is 15 days. Each worm can suck about 0.05 ml of blood per day in sheep (Ijaz et al. 2009). Therefore in acute condition animals may be found dead without showing any clinical signs. However in chronic condition animals show pale conjunctivae and mucous membranes, diarrhea, lethargy, muscular weakness, and edema particularly on lower mandibular region and lesser extend to ventral abdomen. PM lesions are pale mucous membrane, skin and internal organs, and watery blood. Liver is light brown in colour and shows fatty changes. The fat becomes gelatinous. Abomasum contains brownish fluid ingesta in which the worms swim actively and swollen mucous membrane covered with biting red marks. The diagnosis of haemonchosis is usually based upon clinical signs and faecal examination (Saminathan et al.2015). Treatment includes fenbendazole (7.5 mg kg BW^{-1}), thiabendazole (44 mg kg BW^{-1}), ivermectin (200 mg kg BW^{-1}, s/c) and albendazole (5 mg kg BW^{-1}).

Toxocariasis

Buffalo and cattle calves are the major definitive host for pathogenic gastrointestinal nematode *Toxocara vitulorum.* A wide variety of mammals, including pig, sheep, rodents, chicken, quail, non-human primates and human can serve as paratenic hosts for *Toxocara* spp. The disease causes considerable economic losses due to decreased growth rate. *T. vitulorum* is a major cause of buffalo calf mortality in the tropics, where up to 100% of morbidity has been reported in calves. Mortality rates of 30-40%, and up to 80% have been described in heavy infections (Devi et al. 2000; Rast et al. 2013). Mature *T. vitulorum* are found exclusively in the duodenum of 3 to 10 week old calves and unembryonated eggs are shed in the faeces and are not infectious when they are first shed. Calves older than 8 weeks have rapidly declining faecal toxocara egg output, most likely due to development of immunity and ageing of the parasite. *T. vitulorum* eggs can develop into the infective stage in 7 to 12 days at 28-30°C (Devi et al. 2000; Rast et al. 2013). Embryonated eggs can survive in the environment for several months and possibly up to two years. The prepatent period is 21 to 28 days. Pregnant cows become infected by ingesting embryonated eggs from the environment. *T. vitulorum* larvae migrate through the liver, lung, muscle, brain, kidney, lymph nodes, mammary gland and other organs; however, mature worms are not found in the intestines of adult animals. Calves mainly become infected by vertical transmission in milk. The larvae are most abundant in the milk during the first week after calving but have been found for up to 18 days. Few larvae are found in colostrum. *In utero* transmission is either less important than lactogenic transmission or does not occur (Devi et al. 2000; Rast et al. 2013). Larvae in tissues of female adult ruminants can survive for several years and have the potential to infect calves over 1-3 parturitions. The incubation period for *T. vitulorum* is 8 to 21 days in calves. Common clinical signs in calves include anorexia, abdominal pain, diarrhoea or constipation, dehydration, steatorrhea, weight loss, and butyric odour on the breath. Uncommon sequelae include intestinal obstruction or perforation and intussusception. Coughing may also be noticed if parasite migrates to the lungs. In adult cattle and buffalo, the infection is asymptomatic (Devi et al. 2000; Rast et al. 2013). The diagnosis of the disease includes faecal examination for identification of Toxocara eggs, which contains a single dense cell mass within a thick and brown outer shell. Sanitation is important and calf faeces should be removed immediately to prevent the infection of adult ruminants. Toxocara eggs are very resistant to chemical disinfectants but can be destroyed by 1% sodium hydroxide, which removes the sticky outer protein coat and makes the eggs easier to remove but does not kill the developing larvae (Devi et al. 2000; Rast et al. 2013).

Management and control of parasitic or helminthic diseases

First deworming should be started to calves between 10-14 days of age and repeated monthly till 6 months of age. Deworming to the animals above 6 months of age should be done twice a year, once at the beginning and another at the end of the rainy season. Deworming agent should be administered on the back of the tongue rather than into the mouth to avoid rumen bypass. Deworming should be done on a mass scale to reduce the egg load of worms in the soil. Pregnant animals should be dewormed twice, first dose near its calving time and the second dose around 6-7 weeks after calving. If the animals are not responding to the treatment, faecal examination should be done to determine the type of worm and appropriate drug should be administered. To avoid antihelminthic drug resistance, the drug should be changed often and administered in proper dosage. In the areas with snail population (water-logged areas), molluscicides should be administered, because snails are involved in the lifecycle of flukes and schistosomes.

4. Important protozoal diseases

In any system of rearing, if animals are allowed to graze, tick infestation is very common. Ticks often rest on the low-lying brushes and grassy areas, and waiting to attach them to a passing animal or person. Wooded areas specially have a high danger of tick infestation. Each adult tick lays around 3000 eggs and the larvae can survive up to 2-7 months, based on the climate, without feeding. Tick-related problems are most common in animal husbandry and most severe during summer. Ticks transmit variety of diseases, which causes high morbidity and mortality in both animals and humans. Tick borne diseases like Crimean-Congo haemorrhagic fever, Kyasanur forest disease, theileriosis, babesiosis, anaplasmosis, etc poses a major constraint to animal health and productivity. The clinical cases of theileria, babesia and anaplasma infections, examination of blood smear are reliable tool for diagnosis under field conditions. Tick and biting flies cause severe discomfort and allergic reactions to the animal.Tick infestation may vary from mild to severe and due to their feeding on animals, debility and anaemia are commonly observed.

Theileriosis

Theileriosis is the most important tick borne disease, caused by *Theileria annulata* and *T. orientalis* and transmitted by *Hyalomma anatolicum.* It affects cattle and buffaloes, and causes significant adverse effect on their productivity and it is fatal disease if remained untreated. Approximately, 33 million cross-bredcattle and 105 million buffaloes in India are at risk tothis disease with an estimated annual loss of US$ 239.5 million (Minjauw and McLeod 2003). Many cases of both subclinical and severe outbreaks of theileriosis have been reported in India. Sero-epidemiological data from various parts of India showed that 30 to 60% of the cattle were harbouring antibodies against *T. annulata*. Schizogony takes place in lymphocytes and monocytes of blood, lymph node and spleen. The PM lesions are enlargement of the lymph nodes, white foci of various sizes in renal cortex and punched out ulcers in the abomasums. Pulmonary oedema, emphysema, subcutaneous and intramuscular oedema and excessive pericardial and pleural fluid may be found. Enlarged spleen and liver, and meninges may be congested and focal haemorrhages are seen in the brain. Diagnosis of disease includes demonstration of the organisms in the erythrocytes from the peripheral blood smear and schizonts in lymphocytes called as Koch's blue bodies from the smear of biopsy material from lymph node, which is pathognomonic feature of the disease. Anti-parasitic drugs like parvaquone (20 mg kg BW^{-1}) are effective in animalswith clinical signs, but in most of the cases the animalsmay remain as carriers.Buparvaquone (2.5 mg kg BW^{-1}) is more effective in the treatment of*T. annulata* infection in cattle and buffalo. The live attenuated schizont vaccine of *T. annulata*is available in India. In endemic areas, single vaccination provides adequate protection when the animals receive continuous challenge from natural tick infestations (Ray and Bansal 1997).

Babesiosis or bovine piroplasmosis

Babesiosis or tick fever is a febrile disease of domestic animals characterized by huge destruction of RBCs resulting in anaemia, icterus, haemoglobinuria and ascites in later stages. The disease is caused by an intraerythrocytic protozoan parasite *Babesia bovis, B. bigemina* and *B. divergens*. *B. bovis* and *B. bigemina* are transmitted by tick *Rhipicephalus* spp.and *B. divergens* is transmitted by tick *Ixodes ricinus*. In cattle, *B. bigemina* is the primary pathogen and its incidencein indigenous, cross-bred cattle and in buffaloeshas been reported frequently in India. *B. bigemina* occurs in the erthrocytes as pear shaped forms in pairs. Sero-epidemiological data revealed that up to 86% prevalence were reported in Indian dairy animals (Singh et al. 2007). The PM lesions are emaciated carcass with oedema, haemorrhages in subcutaneous, subserous and intramuscular regions. Enlarged spleen and liver, and distended gall bladder with dark green bile. Diagnosis of diseases includes identification of babesia in blood smears and ELISA. Antibabesial drugs like diminazene diaceturate, imidocarb and amicarbalide are effective in animals; however it depends on early detection of the disease.

Anaplasmosis

Anaplasmosis (known as gall sickness) is an economically important rickettsial diseases affecting ruminantscaused by an obligate intra-erythrocytic *Anaplasma marginale*and *A. centrale*and transmitted mainly by *Boophilus microplus*. The organisms invade erythrocytes as initial bodies and develop inside and infect other RBCs . However, it does not cause haemolysis and haemoglobinuria is absent but the infected erythrocytes are phagocytosed by the reticulo endothelial cells in the spleen. Generally, mortality rate is 5 to 40% but may reach up to 70% during fatal outbreak. The most important complication during anaplasmosis is life-long carrier state which occurs in animals that have recovered from the clinical disease. Clinical anaplasmosis was reported from various states of India like Odisha, Uttar Pradesh, Punjab, Haryana, Tamil Nadu, Karnataka, Jammu and from parts of north and central India (Srinivasan et al. 1995). The disease is characterized by fever, anaemia,weakness, constipation, yellowing of the mucous membranes, lack of appetite, depression, dehydration and laboured breathing. Acute form of disease can cause slow recovery leads to loss of milkand meat production. The PM lesions are severe anaemia with pale mucous membrane and icterus. Spleen is greatly enlarged and congested. Enlarged liver with rounded edges and distended gall bladder with granular bile. Petechiae of epicardium and catarrhal gastroenteritis are found. Oxytetracycline (20 mg kg BW^{-1}) is the drug of choice for treatment.

Trypanosomiasis

Trypanosoma evansi causes trypanosomiasis, which is a significant haemoprotozoan infection of horse, camel, donkey, cattle, buffalo, dog and wild animals. Trypanosomes are haemoflagellates and have a characteristic leaf-like body with a single flagellum attaching to the body by the undulating membrane. The outbreaks are reported frequently in water buffaloes in India (Tewari et al. 2013). All domestic animals except camels, the disease is commonly known as Surra and in camels the disease is known as Tibersa. *T. evansi* is the most commonly occurring trypanosome species in India and causes major economic losses in horses and camels (Tewari et al. 2013). *Tabanidae* flies (horse flies and deer flies) are the vectors responsible for the spreading of the disease. The disease causes considerable economic losses due to immunosuppression and huge mortality in precious animals. The disease occurs in all age groups of animals; however incidence is more common during 1.5 to 2 months after rain, because more availability of rain water lodged breeding areas for disease spreading vectors (Rani et al. 2015). Due to subclinical infection, the incidence of trypanosomiasis in cattle and buffaloes has been unnoticed in India and buffaloes may act as reservoirs. When the animals become stress due to long transportation, hard work, overcrowding, malnutrition, inclement weather and other concurrent infections, the infection flare up and become prominent and visible infection. The acute form of the disease in bovine is manifested as emaciation, high fever, lachrymation, corneal opacity, reduced milk yield, nervous signs and mortality often happens within 24 h of onset of clinical signs. Nervous signs include head tilt, circling, blindness, hyper-excitability and paddling movements. Abortions, infertility and stillbirth may occur in buffaloes. Chronic surra is characterized by progressive anaemia, weight loss with loss of reproductive performance (Radostits et al. 2007). Death may occur in 2 weeks to 2 months. Oedematous swellings of the lower parts of the body (legs, briskets and abdomen) may be seen. Lymph nodes also may be swollen.*T. evansi* can be controlled by using trypanocidal drugs, control of vectors and trypanotolarent cattle breed development (Tewari et al. 2013). Diminazene aceturate (7 mg kg BW^{-1}) is the prescribed drug for the treatment of trypanosomiasis in ruminants and should be administered deep intramuscularly.

Coccidiosis

Coccidiosis is one of the most pathogenic intestinal diseases caused by different species of Eimeria belonging to phylum Apicomplexa. The disease causes huge economic losses to the livestock industry due to high mortality and morbidity in young calves aged up to 1 year. The disease occurs mainly in younger animals where as in older animals the immune status plays major role in protection. Coccidia in association with other enteric pathogens cause severe diarrhoea in calves. The disease occurs in acute, subacute and chronic forms. Bloody diarrhea, dehydration, rough hair coat, reduced growth rate, anemia, weakness and weight loss are the clinical signs of coccidiosis (Bastianetto et al.2007). Clinical coccidiosis in cattle mainly depends on factors like species of Eimeria, age of infected animal, number of oocysts ingested, presence of concurrent infections and management practices. The disease is common in Overcrowding, lack of sanitation, confined animals kept under intensive husbandry practices and is more common in housed animals than in those on pastures. More than 13 species of Eimeria and one species of Isospora have been indentified to infect cattle. *Eimeria bovis*, *E. zuernii* and *E. auburnensis* are the most pathogenic species and associated with clinical coccidiosis under field conditions while other species have been shown to be mildly or moderately pathogenic. Of the 15 species of Eimeria of sheep, *E. ovinoidalis* and *E. ahsata* are highly pathogenic. *E. arloingi*, *E. christenseni* and E. *ninakohlykimovae* are highly pathogenic *Eimeria* species of goat.

The major damage is due to the rapid multiplication of the parasite in the intestinal wall, and subsequent rupture of the cells of the intestinal lining. Several stages of multiplication occur before the final stage, the oocyst, is passed in the feces. Oocysts are extremely resistant to environmental stress and are difficult to completely remove from the environment. The disease is transmitted by ingestion of sporulated oocysts. Infection is acquired from contaminated feed, water, soiled pastures or by licking contaminated hair coat. Diagnosis is based on symptoms and microscopic and post mortem examination. Finding of a few oocysts in the diarrhoea of lamb or kids does not necessarily justify the presence of coccidiosis. It is always advisable to depend on necropsy findings than faecal examination (Vegad 2008). Treatment of affected animals includes supportive treatment and administration of coccidiostat drugs to inhibit the coccidian development. Amprolium at 10 mg kg

$BW^{-1} day^{-1}$ for five days and sulfonamides are the commonly used drugs for treatment of clinical disease. Control includes good animal husbandry measures to prevent the ingestion of infective oocysts by other animals. For prevention of disease lasalocid (Bovatec®) 1.0 mg kg BW^{-1} and monensin (Rumensin®) 1.2 mg kg BW^{-1} for 28 days should be administered.

Control of ticks and flies

All newly purchased animals should be completely de-ticked before allowto mixing withother animals in the farm. Acaricides like melathion, asuntol, pyrethrins and amitraz should be used periodically for control of ectoparasites in animals.All cracks and crevices in the cattle shed should be sprayed with higher concentration of the acaricide along with application on the body to avoid re-infestation. Flaming also can be done using a flame gun if available, with a little bit of caution. The acaricide group should be changed often and applied in proper concentration to avoid developing resistance. Veterinarian's proper advice is needed for selection of appropriate acaricide and its dosage. For control of flies, proper manure and urine disposal should be done immediately after its voidance in appropriate place. Any stagnation of drainage water should be avoided.Smoking the shed with raw leaves (neem leaf preferred) especially during evenings would help to reduce the fly nuisance. Fly repellants like neem oil etc. should be applied regularly and in proper concentration to repel the biting flies and ticks. Neem oil does not have any harmful effects of chemicals and chances of resistance developing are also remote. Application should be always done against the direction of the hair and should cover the entire body, especially underbelly and legs.

5. <u>Important fungal diseases</u>

Ringworm infection

Ringworm is one of the commonest skin diseases in cattle. Ringworm is a transmissible infectious skin disease caused by *Trichophyton verrucosum*, a spore forming fungi. The spores can remain alive for years in a dry environment. It occurs in all species of mammals including cattle and man. Although, fungal infections cause little permanent damage or economic loss but sometimes it may cause severe epidemic. Direct contact with infected animals is the most common method of transmission of infection. Spores can germinate and attack the shafts of the hair and the surface layers of the skin. Exudates ooze from the damaged skin and mix with debris from skin and hair forming a crusty scab. The symptoms are grayish white areas of skin with an ash like surface, usually circular in outline and slightly raised, size of lesions are variable, can become very extensive. In calves lesions are most commonly found around eyes, on ears and back. In adult cattle, lesions are more common in chest and legs; sometimes it also occurs indifferent internal organs like lungs, placenta and brain which are very much fatal. Treatment protocol includes amphotericin B @ 0.4-1.5 mg kg $BW^{-1}$for 10-40 days i.v., itraconazole @ 3 mg kg BW^{-1} orally BID for 3-4 months, potassium iodide @ 6-10 g daily orally for 7 days, sodium iodide @ 1 g 12 kg BW^{-1} single i.v. and griseofulvin @ 5-10 mg kg^{-1} orally SID for 3-6 weeks. Prevention of disease includes proper cleaning and disinfection of the environment, which is the major source of infective fungi. Reducing the density of animals and increased exposure to sunlight will prevent the spread of disease between animals.

B. <u>Important non-infectious diseases</u>

Milk fever, ketosis, post-parturient heamoglobinuria, ruminal acidosis and alkalosis, pica and downer's cow syndrome in cattle, buffalo and goats are important production diseases under agroforestry. Milk fever occurs mainly due to calcium deficiency without concurrent deficiency of magnesium. The most likely period of occurrence is within one week post-parturient and subacute calcium deficiency can occur during early lactation and late pregnancy. The treatment of milk fever is administration of calcium boroguconate. Ketosis occurs between 3 to 7 weeks of post-parturient period. Diabatic ketoacidosis has also been recorded in cattle, buffalo and goats. Zinc and insulin is to be administered with constant monitoring of blood and urine glucose levels. Pica is a common problem in cattle, buffalo, camel and goats in agroforetry due to deficiency of minerals especially phosphorus, sodium chloride, calcium, protein, vitamins A, D and E, and helminthiasis mainly round worms (Mathur et al. 2005). Botulism has been reported as a consequence of pica in cattle (Kishore 1998).Successful management of pica includes supplementation of vitamins and minerals (Gahlot 2005). Alkalosis is result from over-feeding of poor quality roughages. Whereas acidosis develops due to over feeding of grain concentrates. The best way to diagnose ruminal acidosis and alkalosis is history, and examination of ruminal and blood pH.

C. <u>Important production diseases</u>

Ruminal tympany (bloat)

Ruminal tympany is excessive accumulation of gases of fermentation with abnormal distension of the rumen and reticulum. The gas may be in the free form or persistent foam mixed with the rumen contents. Primary or frothy or pasture bloat is due to production of stable foam traps the normal gases of fermentation in the rumen. There is inhibition of coalescence of the small gas bubbles and increase in the intra ruminal pressure as eructation does not occur. Bloating forages are alfalfa, red clover, white clover and young green pasture with high protein content. Sudden change in feed/fodder and climate are common predisposing factors. Clinical signs may develop within 15 minutes after going on to bloat producing pasture. The entire abdomen is enlarged with obvious distension of the upper left para lumbar fossa. Discomfort with the animal may stand and lying down frequently, kicking at its abdomen and rolling. dyspnoea, open mouth breathing, protrusion of tongue, salivation, extension of the head and increased respiratory rate are noticed. Sudden death may occur in some animals. Trocarization or passage of stomach tube releases only small amounts of gas. Emergency rumenotomy in severe cases and administration of antifoaming agents, detergent such as dioctyl sodium sulfosuccinate and synthetic surfactant like polaxalene at 25-50 g is recommended.

D. <u>Important diseases caused by phytotoxins</u>

Cyanogenic glycosidepoisoning

Hydrocyanic acid (HCN) or prussic acid is most toxic and rapidly acting chemical. Cyanide poisoning in animals is due to ingestion of certain plants like *Acacia leucophloea*, *Lotus sp.*, *Nerium oleander*, *Sorghum vulgare*, *S. halepense* etc. The content of cyanogenetic glycosides in plants varies with stage of growth, climatic conditions, type of soil and fertilizer used. Young and immature plants, plants growing rapidly after drought, wittled and frost bitten plants are more toxic. Drying of the plant or making silage reduces the toxic potential of the plants. Plants containing cyanogenetic glycosides release HCN due to hydrolysis in the stomach. Ruminants are more susceptible to HCN poisoning than horses and pigs, since the enzyme responsible for the release of hydrocyanic acid are destroyed by the gastric HCl. Cyanide is eliminated through the lungs, the exhaled air is having a characteristic ‘bitter almond’ smell. Excess cyanide in blood and tissues bind to ferric iron of cytochrome oxidase and prevent the transfer of electrons results in functional tissue anoxia. Onset of signs is acute soon after access to toxic material and clinical signs are dyspnea, tremor, recumbency, convulsions (Fig. 4C) and death within a few minutes to hour. PM lesions are cherry red or bright red blood that does not clot, congestion in the gastrointestinal tract and lungs, and peticheal haemorrhages in various organs (Fig. 4D). The treatment of cyanide poisoning consists of administration of sodium nitrite i.v. (converts haemoglobin to methaemoglobin) and sodium thiosulphate (detoxifies cyanmethaemoglobin by converting cyanide moiety to thiocyanate, which is non toxic). In horses and cattle 10 ml of 20% sodium nitrite i.v. followed immediately with 50 ml of 20% sodium thiosulphate. In sheep, 10 ml of 10% sodium nitrite and 10% of 20 ml sodium thiosulphate should be given.

Mimosine (Leucaena leucocephala) toxicity

Leucaena leucocephala (also known as subabul) is a rapidly growing, drought tolerant, palatable and high yielding tropical or subtropical legume. It is enriched in protein foliage (25-35% CP) and other nutritional components. In spite of excellent source of nutrients, *L. leucocephala* forage as well as seed contains a numbers of toxic constituents like mimosine, tannin, protease inhibitor and galactomannan gum which may severely limit its utilization in livestock (Kaul et al., 1983). The toxic amino acid mimosine or leucenol, in ruminants degraded to 3,4-dihydroxypyridone (3,4-DHP), which is a potent goitrogen. The mimosine content varied in different parts of a plant and also depending on season and maturity. The concentration of mimosine in the growing tips of the leaves may reach up to 12%, in pods 3 to 5% and in seeds 3.61 to 5.04% of DM (Gampawar et al. 1988). Toxicity of mimosine is because of inhibition of thyroxine synthesis due to inhibition of tyrosine utilizing enzyme or inhibition of mitotic activity (Hegarty et al. 1976). The clinical signs in cattle include alopecia, loss of appetite, excessive salivation, incoordination of gait, enlarged thyroid and pituitary gland, poor breeding performance, neonatal death and poor growth rate. Symptoms of emaciation, alopecia, scaly skin, ear and eye lesion, ulceration on mouth region, drooling of viscid saliva and even vomiting of thick green slime were observed in calves. In sheep, poor wool growth and hemorrhagic cystitis were reported. Decreased BW, goitre, neonatal death and esophageal ulcers were reported with defleecing in pregnant ewes. Leucaena feeding causes no toxicity symptoms in goats (Paul et al. 1998). The treatment of mimosine toxicity includes supplementation of mineral salts like iron, aluminium, copper and calcium leads to reduction in toxic effects due to the chelation activity and thereby excretion through faeces. Sodium acetate detoxifies 95% of mimosine tn the feed without loss of any important nutrients. Clostridial strain 162, *Synergistes jonsii* and *Streptococcus bovis* bacteria degraded both 3, 4-DHP and 2, 3-DHP in Leucaena fed rumen fluid.

Nitrate and nitrite poisoning

Nitrates are non-toxic, however in the rumen they are converted into nitrites, which are toxic. Nitrite is 6-10 times more toxic than nitrates. Plants that accumulate nitrate when they grow on soils containing excess of nitrates include *Amaranthus retroflexus*, *Brassica napobrassica*, *Chenopodium album*, *Datura sp.*, *Tribulus sp.*, *Beta vulgaris*, *Curcubita maxima*, *Ipomoea sp*. and *Solanaum sp*. Ruminants are more susceptible to nitrates than monogastric animals. Neonates are more susceptible to nitrite toxicity and mechanism of actions are circulatory haemoglobin is converted into methaemoglobin, relaxation of vascular smooth muscle and vasoldilatation results in systemic arterial hypotension and decreased cardiac output. Clinical signs are abdominal pain, diarrhoea, muscular weakness, incoordination, accelerated heart rate, dyspnoea and in severe cases progressive cyanosis which is visible as bluish discolouration of the mucous membrane and unpigmented areas of the body, coma and death. Dark brown or coffee coloured blood which clots improperly, brown staining of tissues, congestion of the intra-abdominal organs, peticheal haemorrhages on the serous surfaces, dilatation of the blood vessels, generalised cyanosis and blood stained pericardial fluid are common postmortem changes. A 'diphenylamine blue test' is used for detecting nitrate in feed/urine/blood/rumen content samples. Treatment includes administration of methylene blue (4-8 mg kg BW^{-1}) i.v. in cattle and sheep as a 1% solution. Methylene blue is an oxidising agent which is reduced to leucomethylene blue by the action of $NADPH_2$reductase. This leucomethylene blue converts methaemoglobin to haemoglobin. A second dose of methylene blue is recommended after 6-8 h. Ascorbic acid is also found to be useful. Large doses of antibiotics can be administered orally to reduce the conversion of nitrate to nitrite by the microflora of the rumen.

Photosensitization

Photosensitization is a clinical condition in which skin is hyper-reactive to sunlight due to the presence of photodynamic agents, which are energized by light. Primary (type I) photosensitization occurs when the photodynamic agent is absorbed either through the skin or from the GI tract and reaching the skin in its native form. Hypericin (from *Hypericum perforatum*; St. John's wort), Umbelliferae and Rutaceae plant families (contain photoactive furocoumarins), species of Trifolium, Medicago (clovers and alfalfa), Erodium, Polygonum, and Brassica have been incriminated as primary photosensitizers in livestock. *Ammi majus* (Bishop's weed) and *Cymopterus watsonii* (spring parsley) have produced photosensitization in cattle and sheep, respectively. Secondary (type III) photosensitization is the most frequent type of photosensitivity observed in livestock. The photosensitizing agent, phylloerythrin (porphyrin), accumulates in the plasma due to impaired hepatobiliary excretion. Phylloerythrin is derived by breakdown of chlorophyll through microorganisms present in the GI tract. When it reaches the skin, it can absorb and release light energy, initiating a phototoxic reaction. Plants causing secondary photosensitization are *Tribulis terrestris* (puncture vine), *Lippia rehmanni*, *Lantana camara*, *Panicum* spp. (kleingrass, broomcorn millet, witch grass), *Cynodon dactylon*, *Myoporum laetum* (ngaio), and *Narthecium ossifragum* (bog asphodel) etc. Scratching or rubbing in the lightly pigmented areas of skin like ears, eyelids and muzzle results in alopecia. Erythema and edema in acute cases and serum exudation, scab formation, and skin necrosis in chronic cases. In cattle, exposure of the tongue while licking may result in glossitis, characterized by ulceration and deep necrosis. If the photosensitivity is hepatogenous, icterus may be present. Treatment involves mostly palliative measures.

E. Pesticides and farm chemicals toxicity

With the frequent use of pesticides and/or farm chemicals in agriculture, especially in the areas under irrigation, risk of poisoning in livestock has increased many folds. This is mainly due to most of the domesticated animals in agroforestry are reared as a component of mixed farming system. Chlorinated hydrocarbons like chlordane, toxaphene, heptachlor; organophosphorus compounds; carbamates like endosulphan, monocrotophos, chlorpyriphos; and chemicals like urea and sodium chloride are the commonest poisoningsagents in livestock in agroforestry (Sharma and Gahlot 1997). Seed dressings, rodenticides and herbicides are another class of miscellaneous chemicals accidentally exposed to animals. Acaricides like melathion, asuntol, pyrethrins, amitraz etc. are also used in control of ectoparasites of animals. Applications of these compounds in higher concentrations than the recommended ones often results into toxicity (Radostits et al.1994).

Strategies for Prevention, Control and Eradication of Diseases in Agroforestry

India carries wide spread presence of animal diseases due to huge livestock population results in difficult to eradicate or control them. Diseases not only affects livestock and their product export, but also results in huge economic losses. Establishment of efficient animal disease surveillance, monitoring and forecasting at the national and regional levels are necessary. Diseases cannot be effectively controlled without timely and accurate diagnosis. Disease management can be of three types: prevention, control and eradication. Prevention involves averting the occurrence of disease in animal populations, where it does not occur already. Control involves reducing the frequency of occurrence or the severity of existing disease. Eradication involves total extirpation of a disease from an area or population. A thorough knowledge on the epizootiology of the disease is necessary for selecting the most appropriate disease management method. Each disease management program must have a clear rationale, objective, plan of action and predetermined method for assessing its efficacy (Saminathan et al. 2016).

Inspite of great multidisciplinary efforts for the eradication and control of animal diseases like contagious bovine pleuropneumonia (CBPP), rinderpest (RP), FMD, BT, PPR, etc. till date, RP is the only disease successfully eradicated from India (Bhanuprakash et al. 2011). India was declared provisionally free from CBPP from October, 2003; however,World Organisation for Animal Health (OIE) declared India is free from CBPP infection during May, 2007 (Singh and Rana 2014). Similar continuous efforts are needed for control and eradication of enzootic diseases present in India, which causes more economic losses every year.

Innovative technologies for disease control

Any control program based on widespread and repeated use of chemotherapeutic agents to kill pathogenic microbes is likely to stimulate development of acquired resistance in the target organism. Such methods are not suitable for control program due to losing their effectiveness in the target host. Fences and other artificial barriers are necessary to restrict animal’s movement to prevent the spread of diseases; however it is expensive, require continuous monitoring and difficult for maintenance. Many countries attained disease free status by employing “test and slaughter” policy. However, in India, only “test and segregation” policy is practically adaptable to control the disease in conjunction with effective preventive measures and control of animal movements. Vaccination is the practical, feasible and effective approach for the control of diseases in our country. Treatment with antibiotics can help to reduce the risk of transmission of contagious diseases. An effective vaccine should reduce the disease incidence, stimulate long-lasting immunity, provide protection against a wide range of infectious agent and should be incapable of reversion to virulence for live attenuated viruses. The proportion of a population that must be vaccinated for disease control is directly proportional to the animal population density and rapid spreading nature of the disease. Conventional diagnostic tools and vaccines need to be updated with recent advanced diagnostics and vaccines for early and confirmatory diagnosis of diseases, and to tackle emerging and re-emerging diseases and help to alleviate the economic losses of farmers (Saminathan et al. 2016).

Newly introduced animals in the farm should always be held in strict quarantine with regular monitoring after they have been confirmed free from disease. Containment followed by eradication, is the method of choice for dealing with newly emerging diseases. The success of an emergency disease control program depends on early detection of the disease and rapid implementation of control measures, which requires extensive prior planning. Concentric quarantine zones are usually established about foci of disease to minimize animal movement into the area and prevent movement out of the area. This may involve radical depopulation and construction of physical barriers such as fences. Management programs that rely on a single technique often fail because of change in the disease, host and the environment. Public education should be included in every integrated disease management programs (Saminathan et al. 2016).

Mass vaccination

Mass vaccination has been the practical approach for control and eradication of several infectious diseases worldwide (Table. 1). Vaccines will protect the livestock by reducing the transmission of infectious agents. In rural areas, basic infrastructure facilities like cold storage needs to be strengthened in veterinary dispensaries to provide improved livestock health services (Bhanuprakash et al. 2011). OIE pathway for control and eradication of diseases includes initial mass immunization, followed by serological surveillance for two years and then no vaccination. These approaches definitely push the country towards free from enzootic diseases results in the declaration of provisional absence of disease(Saminathan et al. 2016).

To attain total disease eradication status in the nation a request/report needs to be submitted to the OIE to officially announce as free from disease, after 3 years of the initial declaration. Two consequent yearly serological screening are necessary during this 2 year period. Therefore, a total of 8 to 10 years is needed for officially to declare any disease free from a particular country (Bhanuprakash et al. 2011). Trained technical, scientific and supporting manpower is required to run a successful disease control program. Veterinarians and para-veterinarians are needed to be trained and equipped for rapid diagnosis of diseases and reporting actions at the district level. The clinicians and diagnostic laboratory personals have to collect the samples from various places frequently like animal fares, veterinary hospitals, slaughterhouses and livestock farms for effective surveillance of the disease.

Balanced nutritional supplementation

Increased scarcity of feed and fodder resulted in weak immune status of the animal leading to increased susceptibility to diseases. Imbalanced nutrition can affect the activity of certain enzymes, which plays major role in immune function. Feeding of balanced ration to cows resulted in enhanced levels of serum immunoglobulins namely, IgG, IgM and IgA, indicating that feeding of balanced ration improves the overall immune status in dairy animals (FAO 2012). Addition of minerals to the ration of dairy animals resulted in greater production of IgG results in better immune status. Subclinical or marginal deficiencies of minerals may be a greater problem than an acute deficiency due to specific signs of deficiency are not evident, however, the animal continues to grow, produce and reproduce but at a lower rate (Garg et al. 2007). Animals under negative energy balance can have extended periods of anovulation. Feeding of balanced ration of energy, protein and minerals should help in improving the disease resistance and reproductive efficiency (FAO 2012). Animals fed on imbalanced diets frequently have a higher load of parasitic infestations that will affect the growth, milk production and general health. Feeding of balanced ration to animals resulted in reduced average eggs per gram (EPG) and an inverse relation exists between the number of gastro-intestinal worms and the level of nutrition; better nutrition decreases the load of intestinal worms (Fekete and Kellems 2007; FAO 2012).

Public-private partnership (PPP)

A lot of successful stories are available regarding PPP in India like ongoing polio control and eradication program. Various non-governmental organizations (NGOs) are significantly contributing to animal husbandry programmes all over the India. Veterinary vaccines and other biological products are produced by government organizations belonging to both state and central. In India, there are 29 biological (vaccines) production centres, among which 22 are under the control and aid of government and 7 are under the control and aid of private sector. Further, many cooperatives are actively contributing for vaccinations, deworming, housing and sheep/goat breeding in many states. The involvement of cooperatives and NGOs are necessary to run the control and eradication programs of diseases. The livestock population is more in India, a large volume of vaccines is needed to implement the programme and hence it is essential to have an association with private manufacturers (Bhanuprakash et al. 2011; Saminathan et al. 2016).

Constraints in the Control and Eradication of Diseases

Initially, the incidence of the disease in animals is reported by the livestock farmers or sarpanch of the village or local village assistant to field veterinarians. At that time, the disease is diagnosed on the basis of clinical signs described by the livestock farmers and majority of infected animal dies by the time veterinarian reaches to the village due to insufficient transport facilities. Due to this limitation, a collection of samples from infected animals and subsequent confirmation of the disease would not be possible. Further, many outbreaks of the disease are not reported frequently, hidden and affected animals were sold at low cost. The areas where a veterinarian can arrive the animal before removal, they are unable to collect the samples because of lack of facilities for collection, preservation and transportation to the adjacent laboratory for diagnosis. A major problem in the control and eradication of diseases using test and slaughter policy is inadequate compensation to the owner for the culling of infected animals. This encourages the owners to hide the clinical sign of the disease in affected areas results in the existence of the disease and animals will act as carriers (Bhanuprakash et al. 2011; Saminathan et al. 2016).

Some Innovative Livestock Production Technologies Under Agro-Forestry System

Any production system is of little importance if it does not have sustainability and better profitability. Generally agro-forestry system on cultivable land is considered as un-economical and should be practiced on waste land. This hypothesis is mainly due to less profitable technologies/ traditional systems, which include livestock rearing also. Agro-forestry is the system which provides much needed sustainability and if critical areas in the production cycle are addressed the profitability can be even better than traditional farming systems. Livestock is well established farming system for eradication of poverty owing to its lower Gini coefficient (0.1-0.2) compared to crops (0.5-0.7). This means that livestock distribution is more equal than land holdings. Any innovative and highly profitable intervention in livestock system will have very positive effect on poverty eradication or economic empowerment of rural masses. It is also a well-established fact that livestock without crops and crops without livestock cannot sustain. In this direction some low cost highly profitable technologies/ improvements developed recently are included here which are suitable under agro-forestry system in agro-climate (Rai et al. 2013a,b,c,d,e).

A. Technologies based on crop- livestock integration

1. Specialized integrated farming system (SIFS) concept for higher profitability

This concept and models have been developed for higher profitability as an extension of integrated farming system which has sustainability but low profitability (Rai et al. 2013c). In the concept we integrate 4 components

(a) Base crops:It provides support to whole system but as such has low profitability. Under it crops may be fodder tree, cereals, horticulture, bovines etc.

(b) Medium duration cash crops:This component has been included to provide much needed bulk cash to the families in medium duration and crops may be fruit crops (banana/ papaya/ citrus etc), goat/ pigs/ aromatic or medicinal plants etc.

(c) Short/ super short duration cash crops:This component provide day to day cash requirements, input costs like germplasm/ labour etc

(d) Value addition:Value addition in the produce is commonly practiced by all but here emphasis is on value addition in the system so that soil health improvement is continuous, use of chemical pesticides/ fungicides is replaced by bio-pesticides, use of IPM, improved compost preparations and systems like biodynamic agriculture/ agnitotra/ rishikheti/ panchgavya systems are integrated to minimize the input cost.

The concepts/ systems are providing around Rs. 1,50,000 thousands acre^{-1}annum^{-1} net income to marginal farmers and sustainable.

2. System of rice intensification (SRI) for draught mitigation

Due to global warming and changing climatic pattern, irregular rain pattern is being witnessed in many parts of the country. If timely rain fails the only solution remains irrigation from ground water which is increasing the cost of production and also not a long term solution for rice cultivation in such areas. SRI is now an old technology and its advantages are well known. A slight modification made the technology to withstand irregular rain pattern with minimum losses. Biomass/ sunhemp/ dhaincha are seeded along with the seedlings which are transplanted at 25 cm rows (prepared by mat nursery method). The dhaincha is mulched around 35th day of transplanting using cono weeder and flooding the field. By 55th day plants regain their vigour and tillering in significant number is visible. The irrigation requirement is twice i.e. at the time of transplanting and mulching. The biomass/ mulch releases moisture to root zone slowly and rest of the water requirement is fulfilled by light showers during the season (Rai et al. 2013d,e).

3. Integration of Morinda citrifolia plantations

Morinda citrifolia is an indigenous plant of coastal belt and requires hot and humid climate for its growth. Though its leaves are used for human as an immunomodulatory but due to its abundance growth in coastal belts it is also widely used as fodder for small ruminants. *M. citrifolia* fed animals became immunodominant results in very low morbidity and mortality. General systemic conditions have been observed at its minimum and many diseases even PPR are rarely reported. The plant can be integrated in the agro-forestry system and can be used for human as well as livestock for general immunity and disease preventions. In our systematic investigations using rat models the fruit juice was able to prevent induced neoplasms and effective in converting invasive neoplasms into non-invasive type when used as curative agent (Saminathan et al. 2013).

4. Ducks as biological control of fascioliosis

Fasciola gigantica is a problematic parasitic disease of bovines and many times create severe economic problems, particularly in hot and humid climate/ months. Its life cycle is indirect and *Lymnaea* snails play as biological host. Cercariae released from them are attached with grasses and enter in bovines to complete their life cycle and thus health problems in bovines. Most of the deworming drugs are ineffective in early stages of the life of parasite and is a costly affair also (Saminathan et al. 2016). We conducted repeated experiments and found that ducks in backyards are very effective in controlling the snail populations in the endemic areas. Though they do not differentiate among snails and break and feed on soft snails including *Lymnaea* snails, thus reducing the population of biological host and controlling the transmission and life cycle of the parasite. We observed that 30 ducks can be effective in controlling the incidence of the fascioliosis in around 100 m radius. In agro-forestry system, due to abundance of moisture and grasses fasciola incidence is generally high and in such situation ducks in backyards can be the best tool to control the disease and have balance in the incidence (Rai et al. 2014).

5. Rural poultry as biological control agent in plantations

In any orchard controlling of insects and pest is a major concern and repeated use of pesticides is only option. Use of chemical pesticides destroys both harmful as well as predator insects. Generally farmers use pesticides when damage is noticed thus already economical loss has occurred. We experimented with rural poultry integration for the purpose. Thus in the same space both plantations as well as high value crop like poultry is taken and the per unit production and profit increases many times. Rural poultry is reared in small shelters 8/12x3x4 ft (LxWxH) and integrated with *in situ* azolla cultivation and feeding. Birds are allowed to graze in the plantations and they prefer insects for their grazing and thus reducing the pest incidence. While plantations provide natural shelter to them and sufficient insects, in turn they are benefitted with poultry droppings and reduction in insects. In our preliminary field experiments we found that for 8-10 m^2 plantation one bird is sufficient (Rai et al. 2013c; Rai et al. 2014).

B. Technologies for boosting livestock production and profitability under agro-forestry systems

1. Mass oestrous synchronization to control infertility

Infertility in bovines is a widely prevalent condition and causes severe loss in dairy sector. The profit of dairy venture in all the systems is severely crippled due to infertility. Estimated annual loss in bovines due to infertility in India is over Rs. 56 billions. Infertility is basically of two major types' viz. anoestrous (not exhibiting oestrous cycle) and of endometrial origin as repeat breeding/ pyometra etc.

Anoestrous: Basically it is of nutritional origin. Sexual maturity in heifers is delayed. Oviparous animals do not exhibit normal oestrous cycle (heat) and thus inter-calving period is prolonged. In normal conditions bovine must conceive within 4 months of calving but in anoestrous conditions the conception is delayed extra ordinarily. Protein, carbohydrates, vitamins and minerals play crucial roles in development of reproductive organs and thus balanced ration feeding make the puberty age normal. In oviparous animals, particularly high milkers, drainage of calcium (Ca) is much higher and reduces Ca in the body. When Ca level is on lower side animals do not exhibit oestrous cycle. Similarly phosphorus (P) level is very important and its low level makes the oestrous weak and prolong without conception. Ascorbic acid is another important factor for development of secretary cells in corpus luteum. Many trace minerals like zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mb) and iron (Fe) play role in synthesis of hormones and electron transfer in development of follicular cysts (ovum) and corpus luteum. Mineral in groups interfere metabolism of other groups thus create problem in absorption and manifestations. Various supplements have been developed and being marketed but the oestrous induction rate under field conditions (including sub marginal conditions) is below 50%. Prostaglandins are used for induction of oestrous but it acts only on mature corpus luteum which is around 20% in field conditions. Thus this therapy mode is not effective. Hormonal treatment is very costly and hampers normal hormone production in body.

To overcome the problem we developed an innovative approach using minerals in special combinations and supported the faster growth of follicles and corpus luteum with vitamins. The preparation, now commercialized to many firms, induces normal oestrous cycle on anoestrous animals with over 85% success rate in field conditions (Rai et al. 2013b; Singh et al. 2013).

Anoestrous is very common in crossbreds and high milk producing animals. Under agro-forestry system it can be reduced by incorporating protein rich fodder plants or tree and supplementing the minerals or preparations as discussed above. Our experiments suggest that profitability in dairy sector can be raised as high as 300% under backyards and in any system it must be above 50% through milk production alone. Integration with the system is must (Rai et al. 2013b; Singh et al. 2013).

Endometritis based infertility: After parturition many pathogens may get entry in genital tract and is very common resulting in inflammation of uterus (endometritis). During oestrous cycle also due to open cervix pathogens may get entry either through infected artificial insemination (AI) equipments or through natural service by bulls. Sometimes following systemic infections pathogens are get localized in uterus and cause endometritis. The clinical form is manifested as pyometra like conditions (swelling of uterus on palpation, discharge of pus from vagina) or repeat breeding conditions. In acute conditions like pyometra generally treatment is done but in sub-acute cases, which highly prevalent in field conditions, the treatment is ignored and severe economic losses are encountered owing to prolonged inter-calving period. Though *E. coli* pathotypes are more common pathogen but other pathogens also play role. In field conditions it is very difficult to establish the pathogens and their importance, it is best to have a blanket therapeutic strategy which effectively treats and cures all conditions. Standard treatment is inducting antibiotic bolus into the uterus during natural oestrous cycle but it has two major limitations viz waiting till oestrous is induced and variable response in recovery. In natural conditions host defence itself takes care and animal recovers by its own but it is uncertain. Therefore, recent approaches have been developed for time bound safe and economic recovery. In one approach, about 40 ml of serum from same animal is collected on the day of oestrous and injected into the uterus on the same day. Animal is cured and may conceive during next oestrous. In second approach, 20 ml of filtered neem oil is injected into the uterus during oestrous cycle consecutively for 3 cycles. The neem oil acts as immune-modulator and condition is cured fully. However, due to wastes of 3 cycle farmers are reluctant to adopt it though highly effective. In the scenario we developed an orally fed economic formulation which controls all the pathogens, neutralizes all the toxins or metabolites, inhibit inflammatory cytokines and thus inflammation and promoted faster healing of endometrium. The recovery rate is much faster and need not to waste the cycle like other treatments and can be given even in suspected cases after insemination (Rai et al. 2013b; Singh et al. 2013).

2. Mastitis

Mastitis is basically inflammation of udder parenchyma in response to infectious and non-infectious causes. In normal course if inflammation is mild the healing is achieved within 6-10 days and no damage or loss occurs. If the inflammation is severe the damaged glandular epithelium is replaced by fibrous tissue and thus permanent loss of milk is encountered from the affected quarter. In infectious causes nearly 137 pathogens have been associated to cause mastitis and include bacteria, viruses, fungi, yeast, rickettsia, etc. In non-infectious causes metabolites entrapped in udder and physical injuries/ insect bites are main causes. Just after parturition metabolites release from uterus enter blood and many time get entrapped in udder and results in severe swelling of udder (Rai et al. 2013a). Toxins or metabolites released after systemic infections are also important cause of mastitis. It has been established that pathogens present as environmental contaminants enter into udder through teat canal and results in inflammatory response. Thus in about 70-80% cases mastitis pathogens enter through teat canal and can be reduced through udder hygiene. The most common pathogens are bacteria and most common genus is *Staphylococcus aureus* and *Streptococcus spp*. Due to its complexity and unresponsiveness to treatment Department of Animal Husbandry, Dairying & Fisheries, Govt. of India has enlisted mastitis as top most problematic disease and FMD has been placed on second position. Annual loss in India due to mastitis is estimated over Rs. 96 billions. The incidence of sub-acute mastitis has been reported as high as 97% but average incidence is placed around 45% (Rai et al. 2014).

The standard treatment of mastitis is based on antibiotic therapy which are administered through teat canal or given parentally. Antibiotics, though costly treatment regime, are effective only against bacterial infection but unresponsive in cases of metabolites or toxin induced or due to other agents. This is the reason for variable and poor recovery rate. Moreover, antibiotic residue in milk is another health concern. Due to these reasons antibiotic therapy and antibiotic sensitivity test is being debated world over. The milk recovery rate in severe cases treated with best antibiotic regime is between 40-65% (Rai et al. 2013a). Keeping in view the situation we developed a different concept of treatment. We targeted inflammation through cytokines, general antimicrobial control, neutralizing metabolites and promoting faster recovery. This approach has been very effective in all types of mastitis, highly economical, orally fed formulation and milk recovery rate has increased up to 90%. The most significant feature is avoidance of fibrosis after recovery and thus no permanent loss of milk. The technology has already been commercialized to multiple firms and work on the concept is further going on (Rai et al. 2014).

3. New rural poultry production technology for poverty alleviation, self-employment and resource generation

This technology has been developed targeting agro-forestry system for mass poverty alleviation, resource generation by poor farmers for diversifying their livelihood base without depending on external borrowings and adopting as self-employment venture in rural areas. The technology is based on semi-range system of poultry rearing and does not require typical poultry shed and balanced feed which are 2 major capital components accounting for more than 80% of input cost. Under agro-forestry system (typical or loose) small shelter is prepared for which height may be kept around 4 ft, width as 3 ft so that roof of asbestos sheet can be prepared and length may be adjusted as per the flock size which may be initially 12 ft for accommodating 250-300 chicks. A door is prepared using waste wood and wire mesh of 2x3 ft dimension. The wall is prepared using mud for thermoregulation and floor is either cemented or made smooth. A brooder is provided inside the shed for initial period of 7-10 days depending on the climatic conditions. In the vicinity trenches of around 4 ft wide and 1 ft deep using thick poly sheet is prepared. *Azolla microphylla* is cultivated using dung and single super phosphate and fed daily adlib. Chicks of dual purpose strains are introduced in the batches of 250-300 at 2 months intervals and disposed off around 4th month when they achieve BW around 1.5 kg. They are fed azolla, and allowed to graze in the vicinity and supplements with 20-30 g brocken grains to fulfill their carbohydrate requirements. The net income per chick is being realized between Rs. 100-125 at 4th month. Similarly in second model the chicks from dual purpose strains targeting egg production are used and introduction of next batch of chicks is only after 6-8 months. Thus landless and marginal farmers are able to get extra Rs. 70000-125000/- net income per annum without any significant initial investment by rotating 4-5 batches per year. The resources generated are used for diversifying their livelihood security base like dairy, goat unit etc (Rai et al. 2013c,e; Rai et al. 2014).

4. Opening of small dairy units with negligible initial cost

Agro-forestry or in any system if profitability is not there, adoption by masses is questionable. On a rough estimate profitability of more than Rs. 1 00 000thousands acre^{-1} landholding at present prices is the attractive preposition for farmers. Dairy unit integration with the system is more acceptable and common in all the agro-systems. It is an established fact that dairy without agriculture and agriculture without dairy is not sustainable and economical in long term. However, starting a small dairy unit is a costly affair and usually unaffordable by resource poor farmers. This concept and validated model has been developed to overcome the cost problem and enhancing the net profit up to 400-500% in medium terms (Rai et al. 2014).

There are 2 situations with farmers i.e. they are having 2-3 low producing bovines which is un-economical and in other situation they want to start it but do not have initial capital cost to purchase the animals. In the first situation mass oestrous synchronization and insemination with improved pedigreed semen is practiced and in 3-5 years these low producing animals establish a high producing small hard of 4-5 animals without any extra cost and even giving extra milk (Rai et al. 2013b). In the second situation, resource generation is practiced and after about 6-7 months first female is purchased costing around Rs 60000/- in the last month of pregnancy or newly calved. The surplus milk sale and further resources generated are pooled to purchase next animal at 3-4 months interval till the size of herd is 4-5 animals. All the animals are made pregnant within 3-4 months of calving using infertility control technology as discussed in the chapter (Singh et al. 2013). Azolla cultivation and perennial fodder are incorporated in the system before starting the venture. In agro-forestry system we observed the cost of rearing is reduced by more than 15%.

Conclusion

Any production system is of little importance if it does not have sustainability and better profitability. Agro-forestry is the system which provides much needed sustainability and if critical areas in the production cycle are addressed the profitability can be even better than traditional farming systems. Livestock is a cash crop and if production level is optimized using technological tools, agroforestry is the best system. Adoption of agroforestry practices in livestock production resulted in increased income to the farmers due to enhanced crop production, reduced labour especially for rearing of cattle and improved soil fertility through application of manure from livestock rearing. Integration of livestock with agroforestry system results in economical and environmentally friendly production of enhanced food and forage simultaneously from the same unit of land. At present agroforestry meets almost 9-11% of the green fodder requirement for livestock, besides meeting the subsistence needs of households for food, fruit, fiber, medicine, timber, etc. Any innovative and highly profitable intervention in livestock system will have very positive effect on poverty eradication or economic empowerment of rural masses. It is also a well-established fact that livestock without crops and crops without livestock cannot sustain.

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Table 1: **Vaccination Schedule for Different Livestock Diseases**

Disease	Host	Vaccine type	Dose	Primary vaccination	Booster vaccination	Revaccination	Month of vaccination
Foot-and-mouth disease	All cloven footed animals	Inactivated polyvalent tissue culture	3 ml in the mid neck region, s/c	4 months and above	1 month after first dose	Annually (every 6 months in endemic areas)	January/February and December
Hemorrhagic septicemia	Cattle and buffalo	Formalin inactivated and $Al(OH)_3$ gel adjuvanted	2 ml, mid neck region, s/c	6 months and above	-	Annually in endemic areas	May-June (adverse climatic conditions like unseasonal rains and cyclones, etc.)
Black quarter	Cattle and buffalo	Alum precipitated BQ vaccine	5 ml, s/c	6 months and above	-	Annually in endemic areas	May-June (before rainy season)
Combined vaccine of FMD, HS and BQ	All cloven footed animals	FMD inactivated antigens, formaldehyde inactivated HS and inactivated *Clostridium chauvoei* mixed with mineral oil emulsion	3 ml, mid neck, deep i/m	4 months	9 months	Annually	June
Brucellosis	Female cattle and buffalo calf	Live *Brucella abortus* strain 19 freeze dried vaccine	2 ml, s/c	4-8 months female calves	-	Once in a lifetime	-
Enterotoxemia (ET)	Sheep and goat	Toxoids of *Clostridium perfringens* type D and adjuvant $Al(OH)_3$ gel	2 ml, s/c	4 - 6 wks of age	2 - 3 wks after first dose	every 6 months	January and July
Anthrax	All species of animals	Suspension of live spores of attenuated non-capsulated strain of *B. anthracis* in 50% glycerinated saline	1 ml, i/m or s/c	4 months and above	-	Annually in endemic areas	May-June
Peste des pettis ruminants (PPR)	Sheep and goat	Live attenuated 'Sungri 96' strain of PPRV in vero cell culture and freeze dried.	1 ml, s/c	4 months and above	-	Every 3 yrs	Before monsoon
Sheep and goat pox	Sheep	Live attenuated 'Romanian' strain of sheep pox virus grown on lamb testicle cells.	1 ml, s/c in neck region	3 months and above	-	Annually	December (after lambing season or during onset of breeding season)
Rabies (post bite vaccine)	All species of animals	Tissue culture CVS strain of rabies virus and adjuvanted with $Al(OH)_3$	1 ml, s/c	Immediately after suspected bite (0 day)	3rd day	7, 14, 28 & 90 (optional) days after first dose.	-
Theileriosis	Cattle	Live schizont grown in lymphoblast cell culture and attenuated by prolonged *in-vitro* passage	3 ml, s/c	3 months of age and above	-	Once in a lifetime.	March

Note: Before any vaccination, deworming should be compulsory to get better results. Only serologically negative female calves should be vaccinated with live *B. abortus* strain 19 while bulls and pregnant animals should not be vaccinated. Theileriosis vaccine only required for crossbred and exotic cattle.