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Challenges and Future Prospects of Livestock and Poultry Farming in Indian Coastal Ecosystem - An Overview

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Indian coastal eco-system has an 8129 km long coastline covering an area of 10.78 M ha possessing about 17% of the total national population. The key activities in the coastal ecosystems include agriculture and allied sectors, industries, tourism, shipping transport, mining, etc. Farming of crops, livestock and fish is the major livelihood source for people in the coastal ecosystem. Besides providing food and earnings, livestock also provides social and cultural standards to the farming community. Coastal regions cover only 14.2% of the total Indian landmass but account for 19.5% of the total Indian livestock population. Coastal India is home to several breeds of livestock like the Vechur cattle of Kerala, Ongole cattle of Andhra Pradesh, Garole sheep and Swamp buffalo of Sundarbans, Nicobari fowls of Andaman and Nicobar Islands, Black Bengal goats, Gir cattle, Billy goat of Barren Island in the Andamans, Chilika buffalo, Kuzi, Kendrapada and Edka sheep of Odisha, Malnad Gidda cattle, Gounti buffalo and Gounti poultry of Karnataka, Agonda Goan pig of Goa, Nicobari, Frizzle, Naked neck and Barred Deshi poultry and Nicobari pig of Andaman and Nicobar Island. However, livestock farming system in the coastal ecosystem faces several challenges such as low productivity, salinity of land, frequent occurrence of natural disasters like floods, cyclones and climate change. Scientific designing of farm houses, feeding, breeding and management and adoption of climate resilient breeds/strains can help in exploiting the full genetic potential of these livestock and poultry germplasm. The development of climate-resilient smart villages, equipped with shelters for both people and livestock, in flood and cyclone-prone regions, along with the implementation of advanced weather forecasting systems, can play a crucial role. These systems would provide timely alerts about impending hazardous events, enabling the adoption of essential preventative measures to safeguard both human and animal lives.

(***Key words:*** *Breeding, Climate, Coastal ecosystem, Livestock, Nutrition, Poultry*)

Coastal regions are the transition areas between land and sea, large inland lakes. Due to good biophysical and climatic environments, and easy communication systems, coastal areas have attracted human settlement since time immemorial. Furthermore, these areas play an important role ecologically, owing to the availability of abundant environmental goods and services. The coastal areas hold both land and aquatic ecosystems, principally in the tropics supporting a rich diversity of flora, fauna and essential natural resources (Singh, 2020).

The coastal ecosystem constitutes estuarine areas, coastal mangrove forests, coral reefs, tidal flats and seagrass beds, home to several coastal and oceanic aquatic organisms. Coastal areas support countless migratory and non-migratory aquatic birds, shore birds, and endangered reptiles like alligators and turtles. The natural beauty and pristine environment of the coastal region allure tourists, therefore, there is tremendous scope for eco-tourism. This region is bestowed with a rich diversity of livestock and poultry resources. Coastal regions cover only 14.2% of the total Indian landmass but account for 19.5% of the total Indian livestock population (Mandal *et al.*, 2022). Livestock and fish farming, duck and chicken rearing along with cultivation of crops like rice, arecanut, jute, oilseed, coconut, etc., are quite popular in this region. However, the coastal belts are largely affected by frequent floods, cyclones, soil salinity and soil erosion, etc., that pose hurdles

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for meeting the food security of the ever-increasing human settlement in and around the coastal areas of the country. The Bay of Bengal is more turbulent and gives rise to cyclones and supercyclones (Maji and Lama, 2016). Land salinization and water logging are the key land degradation processes common in these areas (Burman *et al.*, 2015). Therefore, in the present paper, an attempt has been made to describe the present scenario of livestock and poultry farming in the Indian coastal ecosystem, the hurdles and challenges and the way forward for resolving the issues.

Indian coastal ecosystem

India is blessed with a large coastal ecosystem broadly categorized into the west coast and east coast. Indian coastal ecosystem on the west coast has five states- Kerala (14 districts), Karnataka (3 districts), Goa (2 districts), Maharashtra (5 districts), Gujarat (13 districts) and 3 Union territories - Daman and Diu, Puducherry, Dadar and Nagar Haveli. The east coast covers four states - West Bengal (3 districts), Odisha (11 districts), Andhra Pradesh (9 districts) and Tamil Nadu (13 districts). Indian coastal zone has 8129 kilometres long coastline covering an area of 10.78 million hectares. The east coast and west coast together account for approximately 3.99 lakh km^2 area (ICAR-CCARI, 2015).

Human and livestock population in Indian coastal region

Approximately 50 to 70% of the world's population reside within 100 kilometres of the coastline covering only around 4% of the earth's land (Poyya and Balachandran, 2008), thus relying profoundly on coastal and marine ecosystems for food, house construction, transportation, waste disposal and recreational areas. As per another report (Wikipedia, 2009), coastal zones (within 200 km from the sea) account for <15 % of the global surface area but it is predicted that 75% of the global population is anticipated to live in the coastal zones by 2025. Nearly 40% of highly populated cities of India bearing more than 500,000 population lie on the coast. This region is rich in livestock resources considering the diversity as well as the number. As per Mandal *et al.* (2022), the coastal regions comprise just 14.2% of India's entire land area but account for 19.5% of the total Indian livestock population. In the coastal region of India, the cattle and buffalo population stands at 19.41 and 9.01 million, respectively. Though a steady increase in the population of sheep, goat and poultry in the coastal region has been observed over the years, there has been a decrease in the pig population (Mandal *et al.*, 2022). The east coast is richer in both population and genetic diversity of livestock than the west coast.

Climate of Indian coastal eco-system

The climate of the west coast is predominantly tropical wet and part of Gujarat possesses semi-arid and arid areas. The climatic condition of the east coast is mostly hot humid and tropical dry with some semi-arid conditions in parts of Tamil Nadu. The average temperature varies from 25.0-27.5°C on the west coast and in the coastal zone of West Bengal and Odisha. However, an average temperature of >27.5°C is experienced in the coastal zones of Tamil Nadu and Andhra Pradesh. Nearly all states on the west coast receive an annual rainfall >2500 mm except Gujarat and northern areas of coastal Maharashtra, where the rainfall varies from 1000-2500 mm. The East coast of India receives approximately 1000-2500 mm of rainfall but especially in the coastal West Bengal and Odisha the rainfall is 1500-2500 mm (ICAR-CCARI, 2015). A characteristic feature of the coastal climate is the occurrence of cyclones as the warm waters of the Bay of Bengal and the Arabian Sea provide the energy necessary for cyclone formation. The coastal regions are vulnerable to these tropical cyclonic events, which can result in the loss of lives of humans and animals, and cause severe damage to human settlements, infrastructure, and natural habitats (Mohapatra, 2015; Chauhan *et al.*, 2021; Ghosh and Mistri, 2023).

Farming activities in coastal eco-system

The key activities in the coastal ecosystems include agriculture and allied sectors, industries, tourism, shipping transport, mining, etc. The predominant mass of people living in the coastal areas depends on farming crops, livestock and fish for their livelihood. Besides providing food and earnings, livestock also provides social and cultural standards to the farming community (Ghosh *et al.*, 2021). Numerous crops like rice, pulses, jute, oilseeds, sugarcane, vegetables, spices and fruits are cultivated in coastal belts of India. Coconut farming is profusely popular in coastal belts (Bhattacharyya *et al.*, 2020). The important cultivation systems of coastal

regions of India are as follows: 1. Rice-based farming systems 2. Coconut-based system 3. Areca nut-based system 4. Cashew-based cropping/farming system 5. Animal-based farming system, and 6. Fish-based integrated farming system. Rice is the chief staple food in these regions in addition to others like meat, fish, dairy and dairy products, regional crops, vegetables and fruits. The total rice production in the coastal states is approximately 15.36 metric tonnes, with Andhra Pradesh being the highest followed by Tamil Nadu, Odisha and West Bengal. The average productivity of rice in this region is about 2.20 t ha^{-1} which is on par with the national average. The fishery sector is very vibrant in the Indian coastal ecosystem with 3432 fishing villages and 8.7 lakh fishermen families (ICAR-CCARI, 2015).The water bodies present in the coastal area provide immense prospects for both inland and marine fisheries. Coastal districts commonly have a warm and humid climate which is favourable for the commercial cultivation of horticultural crops, especially coconut, areca nut and cocoa.

Mixed farming and intercrops-based coconut and areca nut cropping systems have promoted overall production as well as sustainable economic returns to the farmers. Integrated farming system offers means to reuse the products and by-products of one component as input material for the other linked component and thereby decreasing the production cost and uplifting total income (Ravisankar *et al.*, 2007). Another emerging and popular farming system is rice-duck farming. Rearing ducks in the rice field is a lucrative and environmentally sustainable option practiced in a few Asian countries.The rice-fish farming system is beneficial for many saline waterlogged areas in both the east and west coasts of India. Rice-fish-prawn/rice-fish-horticulture-livestock-based farming is suitable in non-saline waterlogged, deepwater and low to moderately saline areas (Sen, 2018). Approximately, 200-250 numbers of ducks can be reared in 1 hectare of rice fields (Nayak *et al.*, 2021).

Dairy is in abundance and the presence of dairy co-operatives in the coastal districts of the country is boosting the milk industry. Poultry farming is another profitable option in the coastal areas. Small-scale backyard poultry rearing with coloured dual-purpose birds is popular in the region. Animal husbandry in coastal zone plays a pivotal role in the farming community and agricultural activities to generate sizeable income. Income augmentation for farmers through livestock-crop integrated farming makes the system more sustainable. The vast livestock population and diversity in the coastal zone can be a crucial asset for the country. In contrast to many other natural resources that are likely to be depleted over the years, the livestock production system would remain a sustainable component of the coastal agricultural system.

Livestock potential

The coastal region of India is bestowed with vast livestock diversity. The coastal region of Western Ghats is one of the mega bio-diversity centres with several endemic species. It is one of the global 10 "Hottest biodiversity hotspots" possessing more than 4500 species of flora and fauna of which 35% are endemic. The west coast has several registered and non-registered indigenous breeds *viz.*, Konkan Kalyan goat (ICAR-NBAGR, 2010) and Konkan Kapilla cattle of coastal Maharashtra and Goa, Vechur cattle of coastal Kerala (Singh *et al.*, 2019), and Malnad Gidda cattle, Gounti buffalo and Gounti poultry of coastal Karnataka. The east coast of India is home to several registered and non-registered indigenous breeds of livestock like Garole sheep and Swamp buffalo of Sundarbans, Black Bengal goats and Billy goat of Barren Island in the Andamans (Maiti *et al.*, 2014; Sen *et al.*, 2010), Chilika buffalo (Singh *et al.*, 2021), Kendrapada (Dash *et al.*, 2022), Edka, Ganjam and sheep of Odisha, Ganjam, Dalua breed of goat. Nicobari, Frizzle, Naked Neck, Barred Deshi, and Aseel (Padhi *et al.*, 1999) are the popular indigenous poultry breeds of the region. The livestock breeds found in the region possess certain uniqueness *viz.*, high prolificacy in sheep and goat breeds of the region. Garole, Kendrapara, Edka sheep and Black Bengal goatsare famous for their high fecundity. Billy goats found in the Barren Island of Andaman can thrive during volcanic eruption by migrating to the unaffected side of the island, feeding on the sparse foliage and drinking the seawater (Sen, 2018). Kendrapada sheep are reared in the native tract only under an extensive range system under almost nil input without giving any feed supplementation. (Dash *et al.*, 2022). Garole sheep of Sundarban besides having high prolificacy naturally possess fair resistance to *Haemonchus contortus* and tropical liver fluke infections, FMD and foot rot

diseases and can graze in knee-bound water (Mandal *et al.*, 2017). Chilika buffalo of Odisha coast can thrive on aquatic vegetation and submerged weeds in the brackish water of Chilika lake (ICAR-NBAGR, 2016). Agonda Goan pig of Goa has excellent adaptability to hot-humid climate, high disease resistance, exhibits early sexual maturity, consumes less feed, can utilize local fibrous feeds and is preferred for its low-fat meat (Vikaspedia, 2022). The pork of Agonda Goan pig has high demand in the local sausage industry (Chakurkar *et al.*, 2016). The Nicobari pig found in Andaman and Nicobar is closely associated with the local culture of the Nicobarese tribe (ICAR-CIARI, 2021). Nicobari pigs are semi-feral in nature, well adapted to local conditions and can thrive with little management and have resilience capability for the alarming climate change. ICAR-Central Island Agricultural Research Institute (CIARI), Port Blair, Andaman and Nicobar maintains and disseminates the pure Nicobari pig germplasm (Kundu *et al.*, 2020).

Research conducted in Indian coastal ecosystem

Combating heat stress in the hot and humid climate prevailing in coastal India is a challenge in the era of climate change. In a study in the coastal tropical climate of eastern India, Behera *et al.* (2022a) reported that crossbred cows with 50% Jersey and 50% indigenous (Red Sindhi, Tharparkar, Desi) inheritance were more heat tolerant than those with higher Jersey inheritance when the impact of heat stress on production and reproduction traits considered. Jersey crossbred cows performed better than Holstein crossbred cows during the high heat stress periods (Behera *et al.*, 2022b). The development of climate-resilient livestock and poultry is a solution to today's climate change scenario (Behera *et al.*, 2019). High prolific sheep and goat breeds are unique to the region. Garole sheep (Banerjee *et al.*, 2009; Mandal *et al.*, 2017) and Kendarpada (Dash *et al.*, 2022) sheep are the two highly prolific breeds lambing bi-annually and yielding twins, triplets and quadruplets carrying the beneficial mutation in Fec B gene. In another study, it was concluded that Jersey crossbred cattle (Dangi × Red Sindhi × Jersey) can perform better in the coastal zone of Maharashtra (Desai *et al.*, 2017). Based on a study in the coastal tropical climate of eastern India, Rai *et al.* (2020) advocated housing calves in semi-covered spaces with provisions of plastic coverings during monsoon and winter drafts will help in rearing calves under village conditions.

In coastal India, pig husbandry is a major livelihood for the people and a source of protein for the poor. Weaning of piglets is associated with psychological, nutritional, immunological and oxidative stresses on the piglets. A study on the Nicobari pig concluded that the administration of probiotics enhanced growth and improved the lipid profiles, antioxidant status and immunity of the weaned piglets. Supplementation of probiotics can be advocated for minimizing the weaning stress in the piglets. Piglet anaemia (iron deficiency anaemia) is the key reason for piglet mortality in both organized and unorganized farms. Oral administration of ferrous sulphate @ 30-50 mg kg^{-1} body weight on 2^{nd}, 7^{th},10^{th} and 15^{th} day of birth was optimal to prevent piglet anaemia (ICAR-CIARI, 2021). Integrated farming is the strength of island agriculture and farming of tuber crops, fruits, vegetables and spices integrated with piggery was found successful in the tribal areas of Andaman. Goya, a new improved crossbred variety of pig (Large White Yorkshire X Agonda Goan) has been developed by ICAR-Central Coastal Agricultural Research Institute (CCARI) which can grow up to 100 kg in 10 months and is suitable for the coastal areas.

Backyard poultry farming plays an important role in the socio-economic life of rural farmers of coastal India. The eggs are better in taste and the meat has a distinctive aroma, flavour and texture and hence has more acceptability. Synthetic-colored birds like Vanaraja have resistance to a few common diseases of poultry and the long shank helps the bird to move swiftly for escaping from predator attack (Swain *et al.*, 2008). The birds are maintained at free-range scavenging during day time and shelter is provided during night and rainy periods. The shelter is prepared using bamboo, fishing net, tarpaulin sheet or coconut leaves. About 2-2.5 square feet of space is required per adult bird (Swain, 2006). Grampriya, a synthetic dual-purpose bird is also suitable for backyard poultry in the coastal ecosystem (Swain *et al.*, 2010). Khaki Campbell crosses with Desi ducks of Odisha performed better with respect to egg production parameters under extensive rearing and was recommended for better profit (Mallick *et al.*, 2009). Nicobari fowl were found well suited for egg production, fertility and hatchability where as Naked Neck proved to be more useful as dual purpose breed in

the coastal ecosystem of Andaman and Nicobar Islands (Padhi *et al.*,1999). Improved Nicobari fowl yields 140-149 eggs per annum under intensive selection in village conditions (Padhi *et al.*, 1999).

To harness the full genetic potential of livestock and poultry, it is imperative to implement scientific feeding strategies. This involves analyzing the available feed and fodder resources to optimize production, as highlighted in studies by Naik *et al.* (2012, 2013). To ensure the sustainability of livestock farming, year-round cultivation of fodder should be actively promoted. By cultivating various types of fodder crops suited to the coastal ecosystem, it is possible to replace concentrate mixtures and reduce production costs. Enhancing dairy production in the region can be achieved by providing a combination of leguminous and non-leguminous fodder.

However, a significant challenge in coastal regions is the limited space for fodder cultivation. To mitigate this constraint, the cultivation of tree fodder and its utilization in livestock feeding can prove to be a viable solution (Naik *et al.*, 2012, 2014). Moreover, to maximize the utilization of available land for fodder cultivation, the implementation of an intercropping system can prove highly beneficial. Given the prevalence of coconut and cashew cultivation in coastal areas, the introduction of maize cultivation as an intercrop can be a noble approach to address the problem of fodder scarcity in dairy production. It has been observed that approximately 57% of the total area within a cashew field could be allocated to fodder intercropping, as outlined by Naik *et al.* (2011).

In addition to this, other promising horticultural crops such as coconut, banana, mango, and pineapple can also be effectively intercropped with fodder (Naik *et al.*, 2014). To combat the limitations of land availability for fodder cultivation, the adoption of hydroponics technology can be a valuable strategy. This method involves cultivating green fodder without soil, and it can be achieved using cost-effective materials such as bamboo, wood, GI pipes, brick masonry, or lean-to type shade net greenhouses equipped with micro-sprinkler irrigation systems. This application of hydroponics has the potential to significantly enhance fodder production in the region (Naik *et al.*, 2012, 2015, 2017).

In coastal India, maize stands out as the best choice for hydroponics fodder production (Naik *et al.*, 2017). The practice of storing fodder in the form of silage can be a viable option to address the shortage of fodder during the lean season and to check wastage. However, silage-making in the coastal areas is hindered due to unpredictable rainfall coupled with drainage problems and scarcity of molasses. One approach to overcome these obstacles is to produce silage using bunker silos without additives (Naik *et al.*, 2013). Also incorporating brewer's spent grains into the diet of dairy cows can effectively reduce production expenses (Swain *et al.*, 2012; Naik *et al.*, 2018).

Feeding of Bypass fat (rumen protected fat) can be used as an energy rich feed supplement for sustainable milk production (Naik *et al.*, 2013; Ghosh *et al.*, 2021). The implementation of feed block technology, which involves utilizing compacted roughage blocks can drastically reduce the storage requirement by 7-8 times. This innovation would enable the farmers to store dry roughages like karad grass, paddy straw in less space. Furthermore, the addition of concentrate to these blocks can enrich the nutritional value thereby eliminating the need to feed concentrate and roughages separately (Naik *et al.*, 2014). Feeding homemade concentrate mixture comprising broken rice and other cheaper ingredients can enhance the performance of the livestock and lower production costs (Naik *et al.*, 2013, 2020, 2021). Similarly, feeding cashew apple waste to livestock and poultry can help curtail the cost of production (Swain *et al.*, 2013).

In coastal India, there is ample scope for duck farming to meet the meat and egg requirements (Naik *et al.*, 2022). Ducks are mostly reared in the backyard system and they rely on scavenging for sustenance while shelter is provided during the night. Ducks derive feed from foraging, picking snails, insects, kitchen waste and weeds. However, feeding broken rice (Naik *et al.*, 2020, 2021) and azolla can have a positive impact on egg production, the quality of eggs and meat production (Swain *et al.*, 2020a, b).

Challenges

The coastal region faces enormous challenges in augmenting the yield of crops, flowers, dairy, dairy products, meat, fish and poultry to provide food, nutrition and economic security to the ever-increasing human

population. In addition, the coastal zone suffers from widespread land degradation and soil erosion coupled with the threats of climate change. The key challenges encountered in this region are described below:

Scarcity of feed and fodder

There is a pronounced scarcity of adequate feed and fodder resources in the coastal areas which poses a significant challenge to livestock and dairy production. The unique geographical setting and highly variable and unpredictable weather patterns in these regions make the cultivation of traditional fodder crops difficult. The majority of the farmers are small holders in the coastal region further complicating the situation. In the coastal regions, indigenous cows constitute the largest population of dairy animals, followed by crossbreds and buffaloes. This trend may be attributed to the fact that the desi cows have low maintenance requirements given their higher immunity to diseases and ability to survive on low-quality feeds and fodder (Manabendra and Dipyaman, 2016). Because of the scarcity, farmers in the coastal region mainly rely on limited sources such as non-leguminous green fodder or paddy straw as dry fodder. According to a study by Sabapara (2016), most of the farmers (82%) opted for non-leguminous green fodder for their animals and only 32% of farmers provided their animals a combination of non-leguminous and leguminous green fodder in the coastal area of Gujarat. Due to the scarcity of green fodder and non-awareness regarding silage making in the study area, very few farmers have adopted the practice of silage making. The challenge is further exacerbated by the inadequate availability of grazing land or pastures and suitable fodder crops for livestock production owing to the escalation of salinity levels in the region.

Increased salinity of the soil

Of the total 6.73 million hectares of salt-affected land across India 2.56 million hectares (approximately 30%) lies within the coastal zones (ICAR-CCARI, 2015). Saline soils in these areas are deficient in essential macro and micronutrients such as nitrogen, phosphorus, copper and zinc, resulting in diminished fodder yields. Further owing to heavy rainfall for several months, there is a formidable challenge in the cultivation of green fodder. The shortage of livestock feed, both in quality and quantity, particularly during the dry season, is a key challenge for livestock productivity in this region. The presence of salt-affected water in the region also poses serious issues as drinking can negatively affect the animal's metabolism, digestion and fertility. Moreover, the potential existence of heavy metals and chemical contaminants could harm the cardiovascular, excretory, skeletal, respiratory and nervous systems (Nardone *et al.*, 2010).

Frequent occurrence of natural disasters

The coastal zones of the country, mainly the east coast, are more prone to natural disasters like cyclones, rising sea levels, tsunamis, floods, etc. However, on the west coast heavy rainfall and in a few pockets seawater intrusion are the major problems. These combined factors cause significant damage to both the agriculture and livestock sectors. A stark example is the Super cyclone of 1999, which severely affected the coastal areas of Odisha causing losses of 6.32 lakh animals and 18.83 lakh poultry and affecting more than 1.7 million ha of agricultural land (Roy *et al.*, 2002). The coastal areas of Odisha and Andhra Pradesh were severely impacted by the severe tropical cyclone "Phailin" in October 2013 resulting in the loss of lives, widespread flooding, destruction of houses, agricultural lands and the fishing industry. In Odisha alone, the recorded toll amounted to losses of 6,644 livestock and 172,874 poultry in Odisha (Govt. of Odisha, 2013). In October 2014, Odisha and Andhra Pradesh coasts again faced the destructive force of cyclone "Hudhud" leading to extensive flooding of agricultural lands and the devastation of crops like bananas, coconut and cashew. Cyclone Fani in April 2019 caused severe havoc on the Odisha coast leaving a trail of destruction. The livestock sector suffered a loss of ₹1,206.81 crores by the cyclone Fani (Govt. of Odisha, 2019). Besides, Amphan in May, 2020 was yet another super cyclone which cause catastrophic damages on the east coast, particularly in West Bengal. The east coast is more prone than the west coast as the frequency of occurrence of cyclones over the Bay of Bengal is much higher than the west coast disrupting human and animal lives and destruction of infrastructure and huge economic losses.

Climate change

Climate change is an inevitable and pressing global issue which has far-reaching implications on both natural ecosystems and human societies. As per the 6th

assessment report by the Intergovernmental Panel on Climate Change (IPCC), low-lying areas and coastal regions are anticipated to be at high risk to climate change across the globe. Presently, 896 million people approximately (about 11% of the global population of year 2020) reside in the low-lying coastal zone which is anticipated to cross one billion by 2050. Furthermore, it is anticipated that there would be 20-30 times more frequent occurrence of extreme sea level events by 2050 (IPCC, 2023). The climate-related stresses pose a great threat to livestock within the coastal regions and as temperatures rise and weather patterns become more erratic, these animals face increased stress levels and heightened vulnerability to disease outbreaks. The heat stress due to the hot-humid climate also negatively affects the performance of the livestock (Behera *et al.*, 2022a, b; Rai *et al.*, 2020). Poultry, in particular, is sensitive to temperature fluctuations, often resulting in decreased egg production and compromised growth rates. Moreover, altered precipitation patterns can disrupt the availability of grazing lands and water sources, further exacerbating the challenges for livestock and poultry management. The implications are not only economic, with potential losses for farmers and the agriculture industry, but also concerning food security and sustainability.

Strategies to combat the challenges

Coastal agriculture of India has affluent agro-biodiversity encompassing a wide variety of plants, livestock and fish genetic resources. The region is privileged with plentiful and assured rainfall for promoting agriculture. However, for uplifting the livelihood of the farmers of coastal regions of India, the focus should be on the integrated farming system, mechanization of agriculture, promoting agro-ecotourism, rearing of climate resilient livestock and poultry and improving their productivity.

i. Diversification of farming through different integrated farming models can ensure the proficient use of the available resources and holistic development. By-product of one component compliments as input for the other and thus can augment income generation opportunities of small and marginal farmers.

ii. Modification of the breeding strategies can help the animals improve their reproduction and growth development by increasing their tolerance to climate change and diseases. Adopting several strategies like the use of locally adapted breeds/varieties that sustain well in the climate, genetic improvement of animals by improving the local breed through crossbreeding with climate and disease tolerant breeds. Use of molecular genetic markers for heat tolerance in selection program and adopting livestock production as an adaptation strategy will help in the adaptation process.

iii. Improving livestock productivity to attain self-sufficiency for the coastal belts by scientific feeding practices, better feed and fodder, and uplifting health care facilities.

iv. Promotion of rural poultry and piggery in villages. Enhancing eggs and meat production through alternative poultry species like ducks, quails, and utilization of local feed ingredients to economize the feed cost. Backyard poultry *viz.*, Vanaraja, Grampriya, Giriraja and other dual-purpose poultry have the potential to uplift the livelihood of small-scale rural farmers.

v. Adoption of partial stall-fed rearing of goats as a high revenue earning proposition.

vi. Building scientifically designed housings, scientific feeding of livestock, day to day herd management to improve output, efficient management of grassland, and establishment of climate resilient smart villages with shelters for man and animals in cyclone and flood-prone coastal areas will help in combating the issues.

vii. Efficient weather forecasting for early warning of hazardous weather conditions will allow the farmers to take necessary preventive measures to save human and animal lives from bad weather conditions *viz.*, severe heat and cold waves, heavy rains and thunderstorms, floods, cyclones, tsunamis and disease outbreaks.

viii. Establishment of agro-eco tourism in the coastal areas, effective use of uncultivated barren lands for the production of horticultural crops, rehabilitation of mine reject soils, diversification of brackish water fishery and secondary agriculture should be promoted.

The Indian coastal ecosystem - both east coast and west coast is blessed with vast livestock diversity. Besides food and employment, livestock also provides social and cultural norms to the farming community. The rising human settlement near coastal regions demands a corresponding increase in the production of agricultural commodities, dairy and dairy products, meat, fish and poultry. Livestock and poultry farming have the potential to uplift the living standards of coastal farmers. However, the livestock farming system in the coastal ecosystem faces several challenges such as salinity of land, feed scarcity and frequent occurrence of natural disasters like floods, cyclones and climate change. The locally adapted breeds in the coastal ecosystem have unique attributes like disease resistance, heat tolerance, high fecundity, ability to thrive and perform under low feed input systems. Additionally, these breeds exhibit a remarkable ability to convert poor-quality feeds and fodder into high-quality protein sources in the form of meat, egg and milk. Scientific construction of farm houses, feeding, breeding and day to day management and adoption of climate-resilient breeds/strains can help in exploiting the full genetic potential of these livestock for optimal production. Promoting integrated farming systems, backyard poultry rearing, and encouraging small-scale livestock enterprises can strengthen the coastal livestock production system.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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