Indian J Anim Health (2022), 61(2)- Special Issue: 41-54
DOI: https://doi.org/10.36062/ijah.2022.spl.02022

Invited Review Article

Climate resilient technologies for augmenting livestock production and enhancing farmer's income under smallholder farming system

A. Haldar[1*], D. Kumar[2], M. Behera[3], S. Ghosh[4], S. K. Joshi[5], U. Das[1], A. Kumar[6] and S. K. Roy[1]

[1]ICAR- Agricultural Technology Application Research Institute (ATARI), Kolkata, Zone V, Bhumi Vihar Complex, Block- GB, Sector- III, Salt Lake, Kolkata- 700 097, West Bengal, India; [2]Krishi Vigyan Kendra- Banka, Jagatpur, Banka- 813 102, Bihar, India; [3]Krishi Vigyan Kendra-Angul, Panchamahala, Angul- 759 123, Odisha, India; [4]Sasya Shyamala Krishi Vigyan Kendra, Sonarpur-700 150, South 24 Parganas, West Bengal, India; [5]Krishi Vigyan Kendra-Jharsuguda, Badmal, Jharsuguda- 768 202, Odisha, India; [6]ICAR-Agricultural Technology Application Research Institute (ATARI), Patna, Zone IV, Central Potato Research Station, Sahay Nagar, Patna- 801 506, Bihar, India

Abstract

Of late, climate change is a major concern for current agriculture systems including livestock farming. Agriculture is the primary source of livelihood for about 58.0 per cent of India's population, and over 86.0 per cent of the country's farmers are small and marginal farmers. Climate change is a real hazard to the livelihoods of such smallholder farmers. While the livestock sector plays a crucial role in food supply and food security, livestock both contributes to and is affected by climate change. Climate change is a great threat to livestock farming because of the potential impact on the quality of feed crops and forage, water availability, feed intake, physiology, livestock production, reproduction, livestock products' quality and livestock diseases. Responding to the challenge of climate change on livestock systems requires designing suitable climate resilient technologies which can reduce climatic impacts on livestock. Most of the studies covering climate change effects on the livestock production system, adaptation, and mitigation measures have been reported in developed countries. Of particular interest is to explore some climate resilient technologies (e.g. year round green fodder production in rain fed areas, hydroponic green fodder production, sensor based smart brooder and climate resilient Kadaknath poultry farming) that may be useful locally for augmenting livestock production and income of the smallholder farmers in developing counties like India.

Key words: Climate change, Climate resilient technologies, Hydroponic fodders, Kadaknath poultry, Sensor based brooder

Highlights

- Climate change is a major concern for the agriculture system including livestock farming.
- Climate change is a real threat to smallholder farmers in the world.
- Responding to the challenge of climate change on livestock systems requires designing suitable adaptation and mitigation measures at regional and local levels.
- Documentation of few case studies on some climate resilient technologies that are useful for smallholder farming system.

INTRODUCTION

India is the largest milk producer, 2nd largest producer of vegetables and fruits, 3rd in fish production, 4th in egg and 5th in poultry farming in the World. The most promising fact is that India ranks 2nd in agricultural production in the world. But it is a matter of great concern that the Global Hunger Index 2021 has placed India at the 101 position out of the 116 countries. India is among the 31 countries

*Corresponding Author, E mail: vetavijit@gmail.com

where hunger is considered as serious. While achieving 'zero hunger' by 2030 is a huge task, the entire world faces the effects of climate change. The effects of climate change are not just limited to human beings but also seen in the agriculture-livestock food production system.

The global scientific community makes a consensus that some climate change has already been occurred and that further change is unavoidable (IPCC, 2013; Quere *et al.*, 2014). The continued greenhouse gas (GHGs) emissions at or above current rates will lead to further increase in global warming in this century (WMO, 2014). Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the three major GHGs. Most climatologists agree that the rise in GHGs in the atmosphere results an increase in air temperature as well as an alteration in rainfall pattern with increased frequency and severity of extreme weather events, such as frosts, heat waves, droughts and flood that pose a threat to agriculture and livestock food chain system worldwide (IPCC, 2001; Thompson, 2010). For example, Bangladesh is one of the disaster-prone areas and worst sufferers for global warming and climate change due to rising sea level (Chen *et al.*, 2012).

Climate change is a major concern for current agriculture systems. Agriculture is the primary source of livelihood for about 58.0 per cent of India's population, and over 86.0 per cent of the country's farmers are small and marginal farmers, working on lands smaller than 2 hectares (Agricultural Census, 2015- 16). In Asia and sub-Saharan Africa, almost 90 per cent of the farmers have small farm households smaller than 2 hectares (Lowder *et al.*, 2014). In fact, smallholder farmers constitute the largest proportion of the 570 million farms worldwide (Lowder *et al.*, 2016). Climate change is a real threat to the livelihoods of such 570 million smallholder farmers in the world.

The livestock sector plays a vital role in food supply and food security. Livestock products (meat, milk and eggs) contribute 15 per cent and 31 per cent of the global per capita calorie and protein supply, respectively (FAOSTAT, 2020). As there is a rising trend of human population growth, urbanization, coming up of affluent 'middle class' consumers and improvement in the global standard of living, specially in the tropical and sub-tropical regions of the globe, the preference towards animal protein-based diet is increasing than the grain-based diet (Rae and Nayga, 2010). Livestock origin products are becoming an important agricultural commodity in the global food security arena. Thus, the animal origin food demand is expected to rise by 62 per cent for milk and by 77 per cent for meat by the year 2050 as compared to 2005-07 (Alexandratos and Bruinsma, 2012). Global farm animal production is expected to be doubled by 2050 from the present levels.

Livestock is affected by climate change as well as contributes to climate change. Different livestock rearing systems, animal type, land use, feed type, enteric fermentation, manure management, slaughtering, processing, and storage contribute significantly to the total GHG emissions (Haldar *et al.*, 2022a). The livestock sector contributes 14.5 per cent of global GHG emissions (Gerber *et al.*, 2013) and thus may increase land degradation, air and water pollution, and declines in biodiversity (Steinfeld *et al.*, 2006; Reynolds *et al.*, 2010; Thornton and Gerber, 2010; Bellarby *et al.*, 2013). At the same time, climate change is a great threat to the livestock production system because of the potential impact on the quality of feed crop and forage, water availability, feed intake, physiology, livestock production, and reproduction (Polsky and von Keyserlingk, 2017; Lees *et al.*, 2019; Romo-Barron *et al.*, 2019; Saeed *et al.*, 2019; Gauly and Ammer, 2020; Tedeschi and Fox, 2020). Climate change may also affect the geographical and seasonal distributions of many livestock diseases, particularly vector-borne, as well as many parasites and pests (Bagath *et al.*, 2019; Filipe *et al.*, 2020). The ability of current livestock systems to support livelihoods and meet the increasing demand for livestock products is thus threatened (Godde *et al*., 2021).

Responding to the challenge of climate change on livestock systems requires designing of suitable adaptation and mitigation measures (Gerber *et al*., 2013). There are many adaptation and mitigation options which can reduce climatic impacts on livestock, but the rational use of such technologies needs to be addressed in the farming communities through some planned extension programs. Most of the studies covering climate change effects on the livestock production system, adaptation, and mitigation measures have been made in developed countries. There is a lack of information related to the current use of adaptation and mitigation measures based on location and livestock farming system (Rojas-Downing *et al*., 2017). An attempt has been made to document few case studies on some climate resilient technologies that may be useful to augment livestock production and enhance farmers' income under the smallholder farming system in the Indian context.

Case study 1: Opportunity for round the year green fodder production in rain fed areas

The highest livestock population with highest milk production has been registered in India during the last few decades. However, India is currently facing a deficit of 35.6 per cent of green fodder, 10.95 per cent of dry fodder and 44 per cent of concentrate feed ingredients (IGFRI Vision, 2017). Thus, the livestock of our country suffer from malnutrition or under-nutrition, leading to low productivity (Prajapati *et al*., 2019). While the average milk yield of cattle around the world and in Europe in about 2238 and 4250 kg per lactation, respectively, the average yield of Indian cattle is only about 1538 kg per lactation (Vijay *et al*., 2018). The green fodders from cultivated lands along with collected grasses and top feeds are often fed to cattle and buffaloes (Shashikala *et al*., 2017). Compared with other available dry roughages, green fodder is a natural, highly palatable, and digestible feed enriched with micronutrients helping in improved nutrient digestibility and maintaining in good health and performance of animals (Jemimah *et al*., 2018).

A large number of farmers are not aware about economic benefits of green fodder feeding to dairy animals. At the same time, cultivation of green fodders requires good-quality land, assured source of good-quality irrigation water, higher doses of fertilizers and regular care, apart from good-quality seeds from reliable sources. Moreover, rapid urbanization, shrinkage in pasture lands, climate change, vagaries in monsoon, water scarcity etc. are leading to huge deficit of green fodder in India (Gunasekaran *et al*., 2019). For last 3-4 decades, the total area under cultivated fodder accounts for only 4 per cent of the total cultivated land (8.4 million ha) in the country, and has remained static (Meena *et al*., 2018).

It is really difficult to motivate farmers for using arable lands for fodder cultivation. While continuous cultivation of rice-wheat causes deterioration of soil health, ultimately resulting in decreased production, diversification of rice-wheat systems with fodder crops on a rotational basis can be adopted as a strategy for ensuring year-round fodder availability in India (Banjara *et al*., 2021a; 2021b). The cropping system with forage crops provides a potential alternative to overcome the fodder problem as it utilizes the resources more efficiently (Singh *et al*., 2022).

We have also opportunities for fodder production through alternate land uses, rehabilitation of all kinds of degraded lands under perennial vegetation or mixed kind of fodder cultivation involving leguminous and grass fodders in different seasons (Dagar, 2017). In India, out of 121 million ha of degraded land, 82.6 million ha is estimated to suffer from water erosion, 24.7 million ha from chemical degradation, 12.6 million ha due to wind erosion and 1.1 million ha from physical (mainly due to stagnation of water) degradation (NAAS, 2009). Thus, cultivating green fodder round the year in barren land is a serious challenge for farmers, particularly for marginal and smallholder farmers (Singh *et al.*, 2015). Hence, figuring out the possibility of cultivation of green fodder in barren land is the need of the hour.

A vast area of barren land prevails in Bihar, Jharkhand and Odisha. Banka district of Bihar is one such district where more than 50 per cent of land is barren and/or forest cover. Rain fed agriculture due to lack of assured irrigation is common in the Banka district. The cultivation of green fodder in fertile land for animal feeding is not in practice by the farmers. The annual rainfall is only 1004.5 mm with a severe lack of rain for 6 months from November to April (Fig. 1), resulting in a scarcity of greens throughout the year. Due to the unavailability of green fodders and the huge cost of concentrate feeds, the cost of milk production sounds high. So, the farmers are not much interested to increase the dairy farm size. Since 2015, Krishi Vigyan Kendra (KVK), Banka has come forward to promote green fodder production in the barren land of the Banka district of Bihar through the capacity building of the farmers on the preparation of barren land using compost and agronomic practices for producing green fodder round the year in a planned manner by the cultivation of cowpea, cluster bean and rice bean with bajra and maize in kharif/ monsoon season followed by oat with berseem in rabi/winter season besides stylo, clitoria, hybrid napier and sudan grasses as perennial green fodders. In the rabi season, berseem, oats (multi-cut) and dual-purpose barley have been reported as the choice of green fodders (Kaur *et al.*, 2018). The inclusion of legume and cereal fodder crops together might be a balanced diet to the animals (Kadam *et al.*, 2017). The terrace risers of agricultural fields planted with suitable grasses could help in conserving soil and crop productivity (Ghosh, 2010). Sudan grass with its tremendous capacity to produce higher biomass, could be a good option during the summer and rainy seasons (Hazary *et al.*, 2015). Napier grass having quick re-growth after cutting, has been suggested as an excellent perennial fodder crop (Rusdy, 2016; Negawo *et al.*, 2017).

In the Banka district, the farmers have converted 6.75 ha of barren land into cultivable land for green fodder production in five years. Once the green fodders have been available, concentrate feeding has been reduced by 20

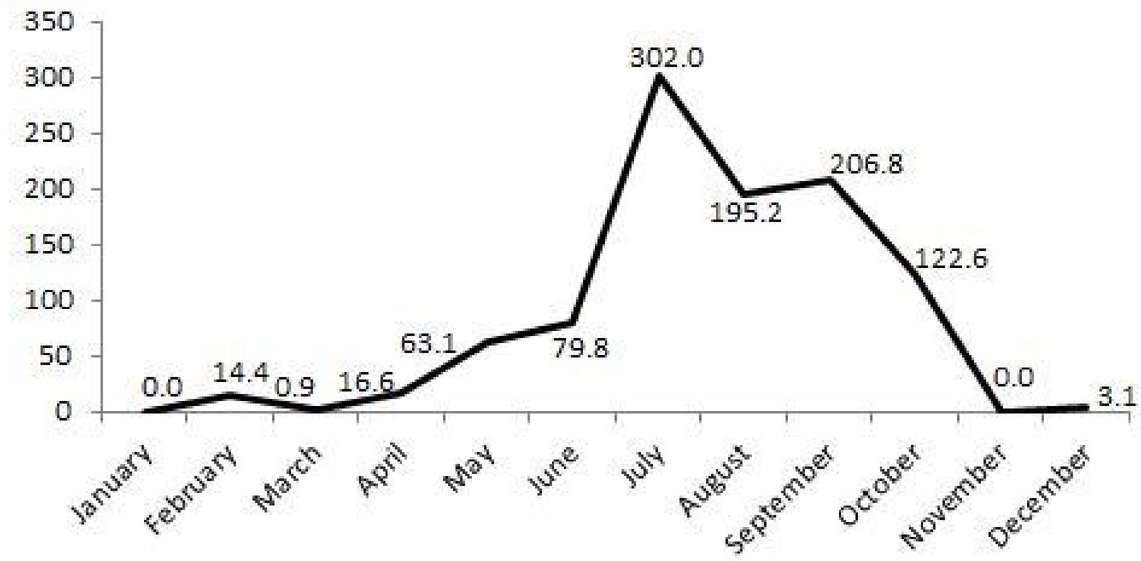

Fig. 1. Monthly average rainfall (1004.5 mm) patterns in the Banka district of Bihar

per cent and intake of dry fodder, particularly straw diminished by 55.4 per cent. The total cost of feeding has been decreased by 16 per cent. The technical knowhow for green fodder cultivation in the barren land of Banka district has not only ensured a significant increase in milk yield but also helped in the maintenance of normal health and reproductive cycle of dairy cows. Green fodder feeding has improved the health status of animals and thus the cost of input on treatment has been decreased from 3.78 per cent to 2.37 per cent of total input. The mortality of calf has also been reduced after feeding green fodders. The net profit has been increased by 25 per cent. Hence, the proper utilization of opportunity for round the year green fodder production in barren land under rain fed situation can meet the shortage of green fodders, decrease the cost of milk production, enhance the net profit and improve green environment too (Meena and Singh, 2014).

Case study 2: Hydroponic green fodder production: An innovative solution in times of drought or water scarcity areas

In recent decades, climate change has an adverse effect on global water availability. The fodder production in the open field requires plenty of water and is sometimes disturbed by sudden climate changes. Of late, hydroponics technology has come up as the best alternative for the production of highly nutritious, palatable green fodders within 7-8 days without soil using nutrient solutions or minimum requirement of water in a confined environment (Al-Karaki, 2011). Only 1.5 to 2 L of water are required to generate 1.0 kg of hydroponic fodder, compared to 454.5, 713.3, 312.5, 267.0, and 555.0 L of water required to produce 1.0 kg of green fodder from berseem, lucerne, oat, sorghum, and cowpea under open field settings, respectively (Singh *et al.*, 2014). While conventional agricultural practices for fodder production require a massive amount of water, hydroponic fodder production is getting attention for water-saving as it uses only 2-3 L of water to produce 1.0 kg of green fodder (Ramteke *et al.*, 2019; Indira *et al.*, 2020; Suma *et al.*, 2020). The basic fundamental of hydroponic fodder production and rationality from water conservation, minimum land use, and least use of chemicals and its benefits for animal production have been reported elsewhere (Bakshi *et al.*, 2017; Shit, 2019; Abdula, 2022).

Climate change has a negative effect on the production and quality of open-field fodder crops for livestock (Rojas-Downing *et al.*, 2017; Attia-Ismail, 2019). Hydroponic plant materials and fodders are rich in protein and energy, and easily digestible (El-Morsy *et al.*, 2013). There is a great nutritional benefit provided by hydroponic sprouted fodder to optimize the general health and performance of young animals while minimizing feed costs (Anonymous, 2013). Since hydroponics fodder is more palatable, digestible and nutritious, it improves immune status of the animals and augments productive and reproductive performance of the animals (Suma *et al.*, 2020). Recent research shows that hydroponic fodder production in a shipping container can reduce GHG emissions (per nutrient mass) by 7.4 per cent compared with conventional farming for barley fodder production (Newell *et al.*, 2021). Hydroponic fodder production is a fruitful growing technology that provides a continuous supply of green fodder all year round, even during worse climatic conditions for sustainable livestock production. In situations, where conventional green fodder cannot be grown successfully, hydroponics fodder can be produced by the farmers using low-cost devices and management.

A case study on the cultivation and feeding of hydroponic green fodder in dairy animals by a farmer has been registered in the Angul district of Odisha. Assured irrigation is the major constraint in the development of agriculture in many parts of an industrial district like Angul of Odisha. Mining activities in the Angul district of Odisha are bringing adverse effects on water, air, natural vegetation and agricultural fields. The annual rainfall is only 1221.8 mm with a

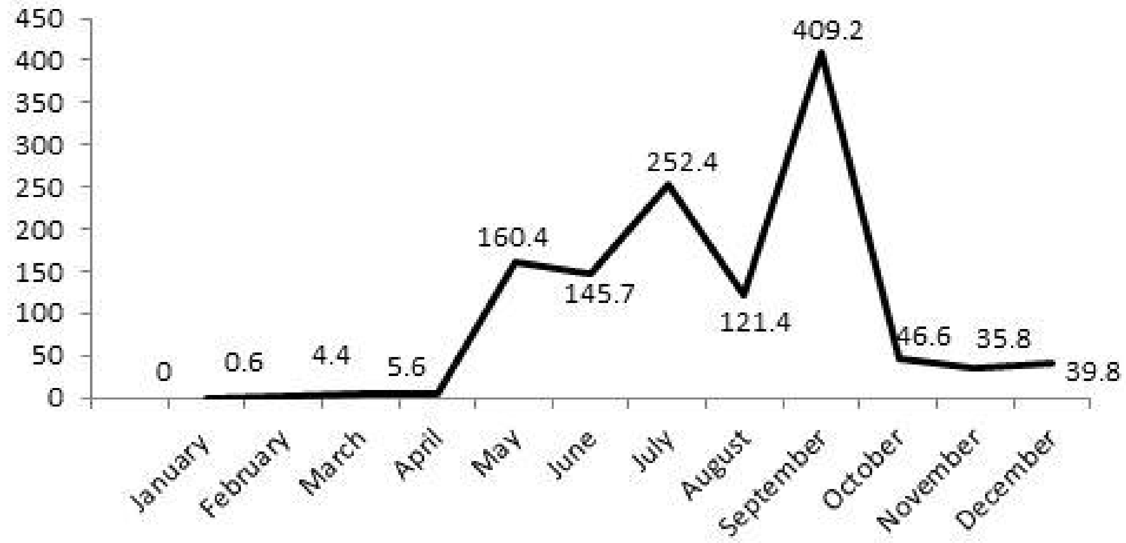

Fig. 2. Monthly average rainfall (1221.8 mm) patterns in Angul district of Odisha

severe lack of rain for 4 months from January to April (Fig. 2). Only 27 per cent of the cultivated land is under an irrigation system in the Angul district. Farmers cultivate only paddy and vegetables. Farmers of Angul district neither grow green fodder in irrigated land nor in less fertile land under rain fed condition. Hence, KVK, Angul planned to make farmers aware of hydroponic green fodder production.

After attending hands on training programs organized by KVK, Angul, Shri. Keshab Singh, hailing from the Village-Purikia, Block-Banarpal, District- Angul, started production of hydroponic green fodder under a low-cost management system in a low-cost house fabricated with brick masonry measuring about 10 ft × 10 ft × 10 ft. The inside of the house had sufficient light and air. Locally available 3-tire bamboo rack of 3 ft wide on all 4 sides was made and placed inside the house. A total of 35-40 plastic tray of a size of 1.5 ft long and 1ft wide was set on the racks in a row. Hydroponic green fodders of maize (*Zea mays*) and wheat (*Triticum aestivum*) were cultivated in plastic trays with a seed rate of 0.350 and 0.250 kg/ft^2, respectively. Each kg of maize grain produced 7.5 kg green fodder, while 1.0 kg wheat grain registered the production of 6.0 kg green fodder within a period of 9-10 days (Fig. 3). Shri Keshab Singh fed hydroponic green fodder to his cows and recorded an increase ($P \leq 0.05$) in total roughage intake and reduction in concentrate mixture intake. The feeding of hydroponic maize fodder in lactating cows replaced maize partially in concentrate mixture (Naik *et al.*, 2017). The incorporation of hydroponic fodders in the dairy ration significantly enhanced ($P \leq 0.05$) milk production per cow per day, reduced ($P \leq 0.05$) the cost for producing each kg of milk and thus increased ($P \leq 0.05$) the net profit per cow per day as reported by Shri Keshab Singh. The milk yield was enhanced by 7.8-13.7 per cent by feeding of hydroponic fodder due to the higher nutrient digestibility (Naik *et al.*, 2014). Farmers in Maharashtra's Satara region reported an increase in milk yield per cow per day and a net profit of Rs. 25-50 per cow per day due to feeding of hydroponic fodders to their dairy animals (Bakshi *et al.*, 2017). The success of Shri Keshab Singh indicated that hydroponic fodder production could be considered as climate-smart agriculture (CSA) practice for providing green fodder in the extreme climatic conditions, where arable land and water scarcity were serious challenges.

Fig. 3. Hydroponic green fodders produced under low-cost management system

Case study 3: Sensor based smart brooder for the reduction of carbon footprint

Energy is the heart of an economy. In today's world, the demand for energy due to the growing population and urbanization is on the rise (Zhang *et al.*, 2017). Energy is indispensable to achieving interrelated economic, social, and environmental goals in sustainable development. However, the increase in the consumption of energy is becoming a threat to the global environment. Energy consumption makes a big contribution in influencing CO_2 emission and thus climate change in the presence of carbon (Tong *et al.*, 2020). The relationship between energy consumption and CO_2 emission indicating reduction in energy consumption can help to reduce the level of CO_2 emission (Chontanawat, 2020; Osobajo *et al.*, 2020). Alternatively, the higher the level of energy consumption, the higher is the carbon footprint (Sasana and Putri, 2018; Sritrisniawati *et al.*, 2022). Increased energy consumption that results in CO_2 emissions and more carbon footprint has a negative impact on the environment and health (Apergis and Payne, 2009). Thus, developing countries face challenges and problems in increasing economic growth and reducing the negative impact of energy consumption on the environment (Shaari *et al.*, 2013).

In a country like India which largely depends on primary industries for the income of the majority of the population, poultry serves as a secondary as well as primary source of income for many families. Poultry farming is one of the energy intensive industries that consume a large amount of energy to provide the suitable indoor environment for chicken health and production like meat and eggs (Cui *et al.*, 2020). Several digital technologies including Information and Communication Technologies (ICTs), Internet of Things (IoT), etc., are now in use with greater gains and efficiencies for smart and precision livestock farming (Haldar *et al.*, 2022b). The livestock farm industry is now the hotspot for the application of these advanced technologies to monitor farm animal in real-time basis. Therefore, the state-of-the-art, innovative environmentally friendly, cost-effective and energy-saving strategies are absolutely necessary in order to decrease operating costs, improve farmers' profits and reduce carbon footprint.

A micro-controller sensor based smart poultry brooding system for efficient electricity use has been demonstrated among the

Fig. 4. Smart brooder with microcontroller and sensor

smallholder farmers by Sasya Shyamala KVK, South 24 Parganas of West Bengal. A total of 14 poultry farmers who had exposure to poultry training from KVK were randomly selected. Out of 14 farmers, 7 farmers used smart brooder and the rest 7 continued with the conventional method of brooding. Each farmer was given 50 numbers of day-old broiler chicks. The smart brooder consisted of one micro-controller (Model No: SZ-7524-P, Subzero, India), one thermo-sensor (NTC, India), cluster of two incandescent bulbs (200 watts each) and one small fan fitted in a wooden frame (Fig. 4). The system used a sensor to detect the temperature of the brooder and maintained the temperature automatically. A threshold for temperature level (95°F) was set that suited for the chicks brooding period. The intelligent system automatically puts off the bulbs when the temperature threshold is exceeded. On the other hand, the conventional brooder was made of a wooden frame with two incandescent bulbs (200 watts each) without any sensor and thermostat. The brooder (smart/conventional) was placed in the middle of the brooding area (40 square feet). Three top drinkers (500 mL) were placed as source of drinking water. Starter feed (EPIC) was provided *ad-lib* on feeding trays. Saw-dust was used as litter materials. To determine electric consumption, one electric meter was connected to each brooder. Standard vaccination schedule and strict monitoring were followed to rule out any possible management errors during the brooding period.

The body weights of birds under smart brooder and under manual brooder did not differ ($P>0.05$) in the present study; however, Corkery *et al.* (2013) reported that smart sensing technologies in poultry houses could enhance growth performance. The excess heat generated from the manual brooder might be a factor for reduced growth performance in manual brooding. There was no mortality of chicks during the trial period. The electric consumption was recorded from both the systems of the brooders and observed that the average electric consumption (93.2 units) in smart brooding system was significantly lower ($P<0.05$) than the average electric consumption (185.8 units) in the conventional brooding system (Fig. 5). Though available literatures (Bea and Malicdem, 2019; Poovendran *et al.*, 2020) indicated that the use of intelligent systems with advanced micro-controllers in poultry house could improve production, the smart brooder saved the electric cost of poultry grower and probably reduced the carbon footprint. Such type smart brooder could provide best temperature zone at each stage of ‘chicks’ growth in which the birds showed the finest performance in terms of the use of feed energy for growth. The temperature sensor

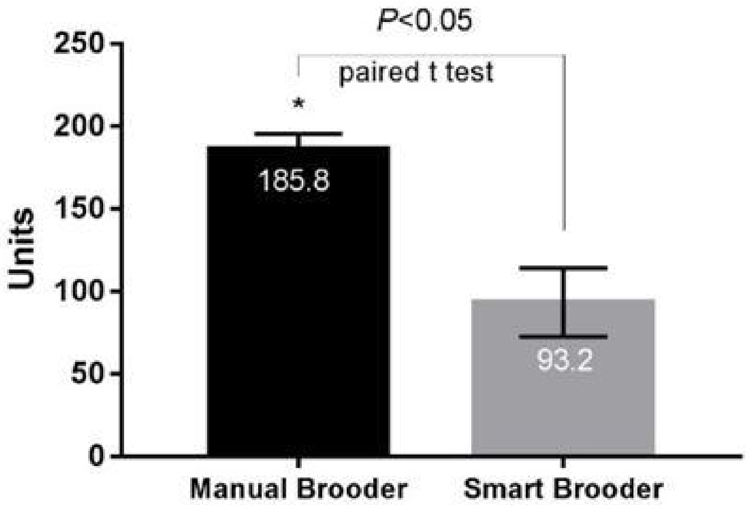

Fig. 5. Comparative electric consumption

based automatic smart brooder could provide an efficient temperature monitoring system to monitor the health and growth of chickens without human interference (Jagdale *et al.*, 2020). Artificially intelligent temperature monitoring system has been reported to use machine learning for real-time temperature monitoring to reduce the cost of brooding and maintaining the air quality by reducing excessive concentrations of air pollutants such as ammonia and CO_2 to increase the productivity of the chickens (Patil *et al.*, 2018). Hence, micro-controller sensor based smart poultry brooding system can be a climate resilient unique technology in terms of cost-effectiveness and reducing carbon footprint in the environment.

Case study 4: Kadaknath: A climate resilient poultry breed

Indigenous livestock and poultry breeds have unique characters that have made them more resilient to local agro-ecological situations. These unique characters are resistant to climatic stresses and diseases and have the ability to ingest and digest low-quality feed. Kadaknath is such an indigenous poultry breed which has supposed to have heat tolerant ability as this poultry breed has been originated from the drought-afflicted Jhabua district of Madhya Pradesh, India (Thakur *et al.*, 2006). The *Kadaknath* breed is strong, climate resilient and highly *protective against* diseases. Unlike broiler *chicken*, this bird can survive even on kitchen waste. The entire bird including plumage, skin, shank including tissues and muscles is black. The black-coloured pigmentation is due to excessive accumulation of eumelanin, a type of melanin pigment in different body parts of this chicken. There are three varieties: jet black, golden and penciled (Parmar *et al.*, 2007).

Kadaknath breed is experiencing higher demand due to its meat quality, texture, taste and perceived health benefits of its meat and eggs (Kanakachari *et al.*, 2022). Kadaknath meat could have beneficial effects to increase blood cells and haemoglobin (Thalkar, 2019). Its black meat is priced three times more than that of broiler chicken. It has got the geographical indication (GI) tag by the Government of India on 30th July, 2018. While the overall progress of backyard poultry farming is limited due to slow growth rate, poor laying capacity, high seasonal mortality and sub optimal management (Rawat *et al.*, 2016). Kadaknath poultry birds has come up as the climate resilient poultry breed with higher growth rate and good laying capacity under backyard system.

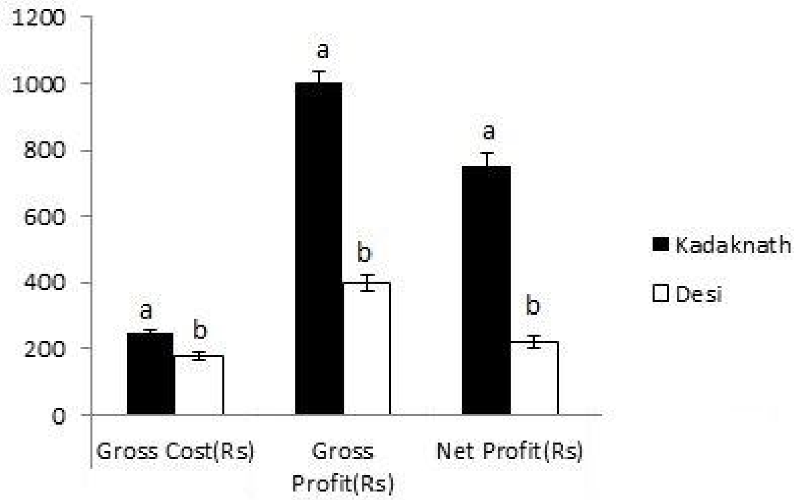

Fig. 6. The benefit cost analysis of Kadaknath vs. Desi birds under backyard system of rearing

Considering scope and potential in regards to supplementary income, additional employment and securing the availability of animal protein to the rural family, Kadaknath farming under backyard system has been promoted in many districts (Jharsuguda, Angul, Ganjam, Sonepur, Keonjhar etc.) of Odisha. Kadaknath birds showed good laying capacity in the climatic condition of Odisha (Jena *et al.*, 2018). In 2018, KVK, Jharsugda planned to test the performance of Kadaknath birds and its socio-economic impact on smallholder backyard poultry farmers in Ghantamal village of Jharsuguda district of Odisha. The farmers of Ghantamal were trained on rearing of Kadaknath birds, supplementary feeding, health management and marketing. Thereafter, each farmer's family was provided with 15 nos. of 21 days old Kadaknath birds. The birds were allowed to free range during the day and confined in a small shed during the night. A handful of grain (broken rice) was given as feed supplement. Lately, cultivation and feeding of azolla was practiced. The birds started laying eggs upon attaining sexual maturity by 130 days. At the initial laying period, the egg size was small (40-45 g), but within a month's period, the eggs attained marketable size (55-58 g). The female and male birds attained average body weights at 4 months of age to 1.8 kg and 2.2 kg respectively, which were higher ($P<0.05$) than that of desi birds at the same age. The annual egg production (average 80 eggs per bird) was higher ($P<0.05$) than that of desi birds. The net profit from Kadaknath birds was found to be significantly higher ($P<0.05$) compared to that calculated from desi birds (Fig. 6).

A farmer, Shri Susant Kumar Naik reported that his family members successfully utilized their leisure time for generating lucrative income with minimum expenditure. They sold birds @ Rs.500/kg live body weight and eggs @ Rs.10/ egg. From 15 numbers of Kadaknath birds, he was able to earn Rs 12,000/- in a year. He further reported that daily food cost of his 5-member family was Rs 320 /-. So, the net income from the backyard rearing of 15 numbers of Kadaknath birds was sufficient to meet the food expenses of the entire family for 37.5 days. After witnessing the success of the family, other farmers of Ghantamal and surrounding villages have shown their interest towards rearing of Kadaknath birds.

Conclusion

Livestock production system has already been established as a major contributor to GHGs for global climate change. The negative effect of climate change on livestock production has also been figured out. However, there is still limited information regarding the impacts of climate change on livestock production systems across different agro-climatic zones in developing countries like India. There is a dearth of information related to the current use of adaptation and mitigation measures to combat the effects of climate change on different livestock species for different locations or regions under varied agro-climatic and socio-economic situations. Hence, livestock farming related mitigation actions need to be addressed at local and regional perspectives. Nevertheless, the available potential mitigation technologies require further testing and refinement at the farmers' field before they can be considered technically feasible and economically viable and culturally fit. A few case studies on climate resilient technologies from Eastern India have been documented in the present study. The involvement of all stakeholders (public and private sector, civil society, research and academic institutions) and support structures are very much needed for enabling the end users towards adoption of such climate resilient technologies. It is thus need of the hour to develop the capacity of the farmers and farmers' family members towards understanding climate change vulnerability and its mitigation measures. Constant education and sensitization are essential in order to aware and make the farmers ready to adopt climate resilient technologies to combat the possible effects of climate change.

Conflict of interest: Authors have no conflict of interest in this study.

Author's contribution: AH: Conceptualized the idea, prepared and edited the manuscript; DK, MB, SG, SJ: Provided data and information for preparing the manuscript; UD, AK, SKR: Helped in editing the manuscript.

ACKNOWLEDGEMENTS

The authors duly acknowledge the farmers for their immense cooperation in conducting the study and providing time-to-time information and data.

REFERENCES

Abdula AH, 2022. Contribution of hydroponic feed for livestock production and productivity. Sci Front, 3(1): 1-7, doi: 10.11648/j.sf.20220301.11

Agriculture Census, 2015-16. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi, India

Alexandratos N and Bruinsma J, 2012. World agriculture towards 2030/2050: The 2012 revision. ESA Working Paper No. 12-03, pp- 1-154. FAO, Rome, Italy

Al-Karaki GN, 2011. Utilization of treated wastewater for green forage production in a hydroponic system. Emirates J Food Agric, 23(1): 80-94, doi: 10.9755/ejfa.v23i1.5315

Anonymous, 2013. Hydroponics fodder feeding system for chickens, goats, pigs, sheep. http://dayton.ebayclassifieds.com [Accessed on 08.10.2022]

Apergis N and Payne JE, 2009. CO2 emissions, energy usage, and output in Central America. Energy Policy, 37(8): 3282-3286, doi: 10.1016/j.enpol.2009. 03.048

Attia-Ismail S, 2019. Impacts of climate change on forages production, worldwide efforts for mitigation and adaptation and the concept of smart-climate agriculture. ARIDLANDS: Biodiversity, Management and Conservation, Nova Science Publishers, Inc, New York, USA, pp 207-223

Bagath M, Krishnan G, Devaraj C, Rashamol VP, Pragna P *et al.*, 2019. The impact of heat stress on the immune system in dairy cattle: A review. Res Vet Sci, 126: 94-102, doi: 10.1016/j.rvsc.2019.08.011

Bakshi MPS, Wadhwa M and Makkar HPS, 2017. Hydroponic fodder production: A critical assessment. Broadening Horizons #48. Feed. a Program. by INRA, CIRAD, AFZ FAO 1-10

Banjara TR, Bohra JS, Kumar S, Ram A and Pal V, 2021a. Diversification of rice-heat cropping system improves growth, productivity and energetics of rice in the Indo-Gangetic plains of India. Agric Res, 11: 31-35, doi: 10.1007/s40003-020-00533-9

Banjara TR, Bohra JS, Kumar S, Singh T, Shori A *et al.*, 2021b. Sustainable alternative crop rotations to the irrigated rice-wheat cropping system of Indo-Gangetic plains of India. Arch Agron Soil Sci, 68(11): 1568-1585, doi: 10.1080/03650340.2021.1912324

Bea JG and Malicdem AR, 2019. Exploring smart sensing technology for brooding. Int J Sci Technol Res, 8: 101-104

Bellarby J, Tirado R, Leip A, Weiss F, Lesschen JP *et al.*, 2013. Livestock greenhouse gas emissions and mitigation potential in Europe. Glob Change Biol, 19(1): 3-18, doi: 10.1111/j.1365-2486.2012.02786.x

Chen CC, McCarl B and Chang CC, 2012. Climate change, sea level rise and rice: Global market implications. Clim Change, 110: 543-560, doi: 10.1007/s10584-011-0074-0

Chontanawat J, 2020. Relationship between energy consumption, CO2 emission and economic growth in ASEAN: cointegration and causality model. Energy Rep, 6(Suppl 1): 660-665, doi: 10.1016/j.egyr.2019.09.046

Corkery G, Ward SM, Kenny C and Hemmingway P, 2013. Incorporating smart sensing technologies into the poultry industry. J World's Poult Res, 3(4): 106-128

Cui Y, Theo E, Gurler T, Su Y and Saffa R, 2020. A comprehensive review on renewable and sustainable heating systems for poultry farming. Int J Low Carbon Technol, 15(1): 121-142, doi: 10.1093/ijlct/ctz048

Dagar JC, 2017. Potentials for fodder production in degraded lands. In: Approaches towards fodder security in India (Ghosh PK, Mohanta SK, Singh JB, Vijay D, Kumar RV, Yadav VK, Kumar Sunil, eds) Studera Press, New Delhi, pp 333-364

El-Morsy AT, Abul-Soud M and Emam MSA, 2013. Localized hydroponic green forage technology as a climate change adaptation under Egyptian conditions. Res J Agric Biol Sci, 9(6): 341-350

FAOSTAT, 2020. http://www.fao.org/faostat/en/ [Accessed on 08.10.2022]

Filipe JF, Herrera V, Curone G, Vigo D and Riva F, 2020. Floods, hurricanes, and other catastrophes: A challenge for the immune system of livestock and other animals. Front Vet Sci, 7: 1-8, doi: 10.3389/fvets.2020.00016

Gauly M and Ammer S, 2020. Review: Challenges for dairy cow production systems arising from climate changes. Animal, 14 (S1): 196-203, doi: 10.1017/S1751731119003239

Gerber PJ, Steinfeld H, Henderson B, Mottet A, Opio C *et al.*, 2013. Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities. FAO

Ghosh BN, 2010. Vegetative Barriers for Erosion Control in Western Himalayan Region. Techn Broch, CSWCRTI, Dehradun, pp 8

Godde CM, Mason-D'Croz D, Mayberry DE, Thornton PK and Herrero M, 2021. Impacts of climate change on the livestock food supply chain; A review of the evidence. Glob Food Sec, 28: 100488, doi: 10.1016/j.gfs.2020.100488

Gunasekaran S, Bandeswaran C and Valli C, 2019. Low-cost hydroponic fodder production technology for sustainable livestock farming during fodder scarcity. Curr Sci, 116(4): 526-528

Haldar A, Mandal SN, Deb S, Roy R and Laishram M, 2022b. Application of information and electronic technology for best practice management in livestock production system. In: Agriculture, livestock production and aquaculture (Kumar A, Kumar P, Singh SS, Trisasongko BH, Rani M, eds) Springer, Cham, pp 173-218, doi: 10.1007/978-3-030-93262-6_11

Haldar A, Samanta I and Patra A, 2022a. Knowledge intensive livestock resource management in a changing environment. In: Sustainable Agriculture Systems and Technologies (Kumar P, Pandey AK, Singh SK, Singh SS, Singh VK, eds). John Wiley and Sons Ltd, pp 117-168, doi: 10.1002/9781119808565.ch7

Hazary MEH, Bilkis T, Khandaker ZH, Akbar MA and Khaleduzzaman ABM, 2015. Effect of nitrogen and phosphorus fertilizer on yield and nutritional quality of jumbo grass (sorghum grass × sudan grass). Adv Anim Vet Sci, 3(8): 444-450

IGFRI Vision, 2017. Indian grassland and fodder research institute. pp 7-23

Indira D, Aruna P, Kanthi S and Kumar K, 2020. Hydroponics as an alternative fodder for sustainable livestock production. World J Adv Res Rev, 5: 87-92, doi: 10.30574/wjarr.2020.5.2.0030

IPCC, 2001. Technical summary: Contribution of working group I to the third assessment report. Intergovernmental panel on climate change

IPCC, 2013. Impacts, adaptation and vulnerability. Intergovernmental panel on climate change. http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-TS_FGDall.pdf [Accessed on 08.10.2022]

Jagdale HV, Jagtap RP, Gorde AS, Gaikwad AM and Pinjari TS, 2020. Automated chicks brooding system using IoT. Int J Adv Res Innov Ideas Educ, 6(5): 1051-1060

Jemimah ER, Gnanaraj PT, Muthuramalingam T, Devi T and Vennila C, 2018. Nutritive value of hydroponic yellow maize fodder and conventional green fodders- A comparison. Int J Agric Sci Vet Med, 6: 98-101

Jena P, Panigrahi B, Panda N, Mohapatra L, Mallik B *et al.*, 2018. Reproductive performance and egg quality traits of Kadaknath in intensive managemental condition under hot and humid climate. Int J Livest Res, 8(12): 105-112

Kadam SS, Arif M and Kumar A, 2017. Role of cropping systems in forage production. Rashtriya Krishi, 12(1): 75-76

Kanakachari M, Rahman H, Chatterjee RN and Bhattacharya TK, 2022. Signature of Indian native chicken breeds: A perspective. Poult Sci J, 78(2): 421-445, doi: 10.1080/00439339.2022.2026201

Kaur R, Kapoor R, Vikal Y and Kaur K, 2018. Assessing genetic diversity in dual purpose oat (Avena sativa L.) cultivars based on morphological and quality traits. Int J Curr Microbiol Appl Sci, 7(5): 1574-1586, doi: 10.20546/ijcmas.2018.705.187

Lees AM, Sejian V, Wallage AL, Steel CC, Mader TL *et al.*, 2019. The impact of heat load on cattle. Animal, 9: 322, doi: org/10.3390/ani9060322

Lowder SK, Skoet J and Raney T, 2016. The number, size, and distribution of farms, smallholder farms, and family farms world wide. World Dev, 87: 16-29, doi: 10.1016/j.worlddev.2015.10.041

Lowder SK, Skoet J and Singh S, 2014. What do we really know about the number of farms in the world? ESA Working Paper No. 14-02. Agricultural Development Economics Division, Rome, Italy, FAO

Meena LR, Kochewad SA, Kumar V, Malik S, Kumar S *et al.*, 2018. Status of fodder production in the existing farming systems in Muzaffarnagar district of Uttar Pradesh. Range Manag Agrofor, 39(2): 313-318

Meena MS and Singh KM, 2014. Fodder production scenario and strategies for revitalizing fodder production technologies. Munich Personal RePEc Archive, pp 1-15

NAAS, 2009. State of Indian Agriculture. National Academy of Agricultural Sciences (NAAS), New Delhi, pp 256

Naik PK, Dhawaskar BD, Fatarpekar DD, Karunakaran M, Dhuri RB *et al.*, 2017. Effect of feeding hydroponics maize fodder replacing maize of concentrate mixture partially on digestibility of nutrients and milk production in lactating cows. Indian J Anim Sci, 87: 452-455

Naik PK, Dhuri RB, Karunakaran M, Swain BK and Singh NP, 2014. Effect of feeding hydroponics maize fodder on digestibility of nutrients and milk production in lactating cows. Indian J Anim Sci, 84(8): 880-883

Negawo AT, Teshome A, Kumar A, Hanson J and Jones CS, 2017. Opportunities for napier grass (Pennisetum purpureum) improvement using molecular genetics. Agronomy, 7(2): 28, doi: 10.3390/agronomy7020028

Newell R, Newman L, Dickson M, Vanderkooi B, Fernback T *et al.*, 2021. Hydroponic fodder and greenhouse gas emissions: A potential avenue for climate mitigation strategy and policy development. Facets, 6: 334-357, doi: 10.1139/facets-2020-0066

Osobajo OA, Otitoju A, Otitoju MA and Oke A, 2020. The impact of energy consumption and economic growth on carbon dioxide emissions. Sustainability, 12(19): 7965, doi: 10.3390/su12197965

Patil S, Kulkarni O, Bairagi P, Taware K, Shetye A *et al.*, 2018. Artificially intelligent temperature monitoring system for prudent brooding. Int J Res Sci Eng Res, 9(9): 1412-1416

Polsky L and vonKeyserlingk MAG, 2017. Invited review: Effects of heat stress on dairy cattle welfare. J Dairy Sci, 100(11): 8645-8657, doi: 10.3168/jds.2017-12651

Poovendran R, Shaguftha S, Shanthini R, Nair S and Srilekha R, 2020. Intelligent system for brooding process in poultry farming. Int J Innov Res Technol Sci Eng, 9(1): 170-176

Prajapati B, Prajapati J, Kumar K and Shrivastava A, 2019. Determination of the relationships between quality parameters and yields of fodder obtained from intercropping systems by correlation analysis. Forage Res, 45(3): 219-224

Quere CL, Peters GP, Andrew RM, Boden TA, Ciais P *et al.*, 2014. Global carbon budget 2013. Earth Syst Sci Data, 6: 235-263

Rae A and Nayga R, 2010. Trends in consumption, production and trade in livestock and livestock products. Washington, DC, Island Press, pp 11-34

Ramteke R, Doneria R and Gendley MK, 2019. Hydroponic techniques for fodder production. Acta Sci Nutr Heal, 3: 127-132

Rawat SK, Gupta R and Narain S, 2016. Study on the performance of backyard poultry production reared by rural woman in Mahoba. Indian Res J Ext Edu, 15(4): 24-28

Reynolds C, Crompton L and Mills J, 2010. Livestock and climate change impacts in the developing world. Outlook Ont Agric, 39(4): 245-248, doi: 10.5367/oa.2010.0015

Rojas-Downing MM, Nejadhashemi AP, Harrigan T and Woznicki SA, 2017. Climate change and livestock: impacts, adaptation, and mitigation. Clim

Risk Manage, 16: 145-163, doi: 10.1016/j.crm.2017.02.001

Romo-Barron CB, Diaz D, Portillo-Loera JJ, Romo-Rubio JA, Jimenez-Trejo F *et al.*, 2019. Impact of heat stress on the reproductive performance and physiology of ewes: A systematic review and meta-analyses. Int J Biometeorol, 63: 949-962, doi: 10.1007/s00484-019-01707-z

Rusdy M, 2016. Elephant grass as forage for ruminant animals. Livest Res Rural Dev, 28(4): 1-3

Saeed M, Abbas G, Alagawany M, Kamboh AA and El-Hack MEA, 2019. Heat stress management in poultry farms: A comprehensive overview. J Therm Biol, 84: 414-425, doi: 10.1016/j.jtherbio.2019.07.025

Sasana H and Putri AE, 2018. The Increase of Energy Consumption and Carbon Dioxide (CO2) Emission in Indonesia. E3S Web of Conferences, 31: 01008, doi: 10.1051/e3sconf/20183101008

Shaari MS, Hussain NE and Ismail MS, 2013. Relationship between energy consumption and economic growth: empirical evidence for Malaysia. Bus Syst Rev, 2(1): 17-28

Shashikala T, Susheela R, Naaiik RB, Shanti M, Devi KBS *et al.*, 2017. Forage resources of Telangana state and research technology for enhancing fodder production. Int J Econ Plants, 4(4): 162-169

Shit N, 2019. Hydroponic fodder production: An alternative technology for sustainable livestock production in India. Explor Anim Med Res, 9(2): 108-119

Singh DN, Bohra JS and Banjara TR, 2019. Diversification of rice-wheat cropping system for sustainability and livelihood security. In: Crop Diversification for Resilience Agriculture and Doubling Farmers Income (Rathore SS, Shekhawat K, Rajanna GA, Upadhyay PK, Singh VK, eds). ICAR-Indian Agricultural Research Institute, pp 78-91

Singh DN, Bohra JS, Tyagi V, Singh T, Banjara TR *et al.*, 2022. A review of India's fodder production status and opportunities. Grass Forage Sci, 77(1): 1-10, doi: 10.1111/gfs.12561

Singh RKP, Singh KM, Jha AK and Abhay Kumar, 2015. A micro analysis of fodder production and marketing in Bihar. Indian J Anim Sci, 85(12): 1379-1383

Singh SK, Mishra JB, Singh SK, Rai MJ, Baig N *et al.*, 2014. Water requirement estimates of feed and fodder production for Indian livestock vis a vis livestock water productivity. Indian J Anim Sci, 84: 1090-1094

Sritrisniawati SE, Agmulia AIA and Gravitiani E, 2022. Imperical study on energy consumption, carbon footprint, and economic growth in Indonesia. IOP Conf. Series: Earth Environ Sci, 986: 012047, doi: 10.1088/1755-1315/986/1/012047

Steinfeld H, Wassenaar T and Jutzi S, 2006. Livestock production systems in developing countries: status, drivers, trends. Rev Sci Tech, 25(2): 505-516

Suma TC, Kamat VR, Sangeetha TR and Reddy M, 2020. Review on hydroponics green fodder production: enhancement of nutrient and water use efficiency. Int J Chem Stud, 8: 2096-2102, doi: 10.22271/chemi.2020.v8.i2af.9060

Tedeschi LO and Fox DG, 2020. Ruminant nutrition system. An applied model for predicting nutrient requirement and feed utilization in ruminants, vol. 1, Xan Edu Publishing Inc. https://www.amazon.com.au/Ruminant-Nutrition-System-Vol-Requiremnt/dp/1975077016 [Accessed on 08.10.2022]

Thakur MS, Parmar SNS and Pillai PVA, 2006. Studies on growth performance in Kadaknath breed of poultry. Livest Res Rural Dev, 18(8): 1-15

Thalkar MG, 2019. Kadaknath poultry farming in India. Agric Food, e- Newsletter

Thompson LG, 2010. Climate change: The evidence and our options. Behav Anal, 33: 153-170, doi: 10.1007/BF03392211

Thornton PK and Gerber PJ, 2010. Climate change and the growth of the livestock sector in developing countries. Mitig Adapt Strateg Glob Change, 15: 169-184, doi: 10.1007/s11027-009-9210-9

Tong T, Ortiz J, Xu C and Li F, 2020. Economic growth, energy consumption, and carbon dioxide emissions in the E7 countries: A bootstrap ARDL bound test. Energ Sustain Soc, 10: 20, doi: 10.1186/s13705-020-00253-6

Vijay D, Gupta CK and Malviya DR, 2018. Innovative technologies for quality seed production and vegetative multiplication in forage grasses. Curr Sci, 114(1): 148-154

WMO, 2014. Weather and climate: engaging youth. World Meteorological Organization. WMO Bull, 63(1): 1-44

Zhang C, Zhou K, Yang S and Shao Z, 2017. On electricity consumption and economic growth in China. Renew Sustain Energy Rev, 76: 353-368, doi: 10.1016/j.rser.2017.03.071

Received- 17.10.2022, Accepted- 27.11.2022, Published- 01.12.2022 (Print)
Section Editor: Dr. A. K. Patra, Associate Editor