Ann. Anim. Sci., Vol. 23, No. 4 (2023) 1037–1047 *DOI: 10.2478/aoas-2023-0027*

sciendo

SUSTAINABLE INTENSIFICATION – REACHING TOWARDS CLIMATE RESILIENCE LIVESTOCK PRODUCTION SYSTEM – A REVIEW

Ruchi Singh[1♦], Sanjit Maiti[2], Sanchita Garai[2], Rachna[3]

[1]Veterinary and Animal Husbandry Extension Education, CVSc and AH, NDVSU, Jabalpur (M.P.)
[2]Dairy Extension Division, ICAR – National Dairy Research Institute, Karnal-132001, Haryana,India
[3]College of Dairy Science and Technology, LUVAS, Hisar-125001, Haryana, India
♦Corresponding author: drruchivet@gmail.com

Abstract

An ability to prepare, recover and adapt to frequent climatic variation is called "climate resilience." Climate change now places additional pressure on the cattle industry, particularly in developing nations, which threatens the livelihood of small farmers. In 2013 "Food and Agriculture Organization" reported that the livestock sector accounts for nearly one-third of agricultural gross production value globally. There are higher possibilities of the effective implications of sustainable intensification in the livestock production systems to determine production pathways that are more sustainable and productive with a minimum negative impact on the environment. The paper discusses the systematic review mingled with qualitative text analysis to explore the interrelation between sustainable intensification and resilient climate practices, specifically towards the livestock production system. The data for systematic review was taken from Scopus, Web of Science, and PubMed databases from 1995 till 2020, with total screened 94 articles in the final selection. The study's results revealed that all approaches involving environment-friendly practices with higher production efficiency, resource use efficiency and reachable to every farmer were considered sustainable intensification. The relevance of this sustainability analysis to climate resilience is illustrated by considering different types of livestock systems with concerned practices. So, the inclusion of appropriate technology in an appropriate system will open the door for sustainable intensification in the face of a climate-resilient livestock production system and finally lead the farming community towards sustainable development.

Key words: food security, climate resilience, sustainable intensification, production system, climate change and adaptation

Natural processes have caused climates to shift significantly, as is seen in the Earth's history, but in the past 50 to 100 years, these kinds of changes have been huge and are occurring rapidly as compared to other changes on the planet ever since the documented history of mankind (IPCC, 2013). "Climate Resilience" is the capacity to predict, recover from, and adapt to these effects (C2ES, 2019). In climate change vernacular, 'resilience' is an increasingly common word used in the present context. India and other developing nations are comparably more sensitive to climate change than affluent nations because agriculture and livestock predominate in rural economies (Kumar et al., 2017). High and frequent variability in climate poses extra challenges to livestock origin production of food, notably in developing nations. At an equivalent time, due to human activity, which is the primary reason behind the deterioration of our planet, various planetary limits have been crossed (Rockström et al., 2009), and therefore, the agricultural sector has become vulnerable with livestock food systems enhanced (Beroya-Eitner, 2015; Steffen et.al, 2015). In present context of food security, livestock plays an important role. Sustainability is a big challenge for livestock in agricultural development. The main objective of sustainable agricultural development is to provide nutrition and food security for everyone, both in the future and now. One-third of the value of worldwide agricultural gross output in 2013 was attributed to the livestock industry (FAOSTAT, 2013). It significantly improves their nutrition and livelihoods, especially for the poor and vulnerable in developing countries. According to common estimates, 600 million impoverished farmers (http://www.livestock-globalalliance.org/) make up the 1.3 billion people who rely on livestock for their livelihoods. The livestock industry sums up for 40% of the worldwide agricultural "Gross Domestic Product" (GDP) and contributes more than 33% of the world's protein consumption. In addition to the danger of illness (because of warmer temperatures), climate change may impact the quantity and quality of fodder and feed and hasten the deterioration of grazing areas (due to greater risk of drought or flood).

Additionally, their contribution rises faster than that of grains. Nearly one-third of the protein that the humans consume worldwide comes from livestock and other ani-

mal dietary sources (Popp et al., 2010). In addition, the livelihood of about a billion of the world's poorest people and almost a billion jobs have been created by the global livestock industry (Hurst et al., 2005). Therefore, managing the livestock industry effectively is key to meeting the U.N. sustainable development goals in many developing countries while also addressing global food production and consumption difficulties (Herrero and Thornton, 2013; Jabareen, 2013; Kissinger and Rees, 2010).

As discussed above, it can be stated that sustainable intensification approach results in increase in food production from farmlands in such a way that has a lower environmental impact (Pretty et al., 2011) and which does not undermine our future capability to continue production of food and make climate resilient livestock production system. The intensification encompasses a Janus face (Kuyper and Struik, 2014), i.e., it had a double meaning in that it made it possible to feed the rapidly expanding population by using an increasing number of natural resources while also eroding agricultural ecosystems' resilience and their capacity to feed people for a very long time. Intensification here focuses on "resource use efficiency". Therefore, there are more opportunities for low-income nations to choose manufacturing routes that are more productive, ecologically benign, and sustainable. Partners in research and development are essential in advancing climate-smart livestock practices which strengthens the rural communities, enhances the employment and livelihoods of small farmers, and prevents detrimental cultural and social effects like forced migration and tenure loss. Reaching towards sustainable intensification, we should conjointly create a minimum of two ways for reaching this first via "de-intensification" in systems with high input and making such systems sustainable, and one concerning the filling of massive yield gaps by extended use of inputs and thereby higher yields. Thus, "sustainable" and "intensification" aim to increase food production with an improved environment and services (Kuyper and Struik, 2017). Hence, the present review discusses the various aspects of sustainable intensification, climate resilience intervention and how all these practices are utilized as complementary to get food security in changing climate.

Material and methods

Therefore, practices under sustainable intensification in a livestock production system that apply ecological principles to systems and contribute in developing a system of livestock production towards climate resilient systems (Maia et al., 2018) were discussed in detail. And highlighted whether the term sustainable intensification is a new paradigm or, we can say, new wine in old bottles. Here, the author discusses the practices included in both sustainable intensification (classified as socio-economic, ecological, and genetic intensification) (Montpellier Panel, 2013), as well as resilient climate practices for the livestock sector (land-based and intensive livestock system-based practices/technologies). To explore this argument, this research has used "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" PRISMA (Moher et al., 2009).

By using the guideline of the PRISMA, we adopted the following methodology for review based on certain keywords in different combinations and permutations as 'sustainable intensification'; 'climate smart/resilient livestock production practices'; 'impacts'; 'sensitivity'; 'adoption' 'resilience' to cope up with 'climate change, livestock production system'; 'food security' etc. The authors searched databases between the dates 1st September and 16th December 2020. The search was run on articles available in Scopus, Web of Science and PubMed with annual reports of various institutes and unpublished thesis. The search concluded with 164 articles. Inclusion (based on keywords, construct) and exclusion (grey literature) were subjected to criteria, and 94 papers were ultimately selected. These were thoroughly examined and further studied.

Steps followed in PRISMA

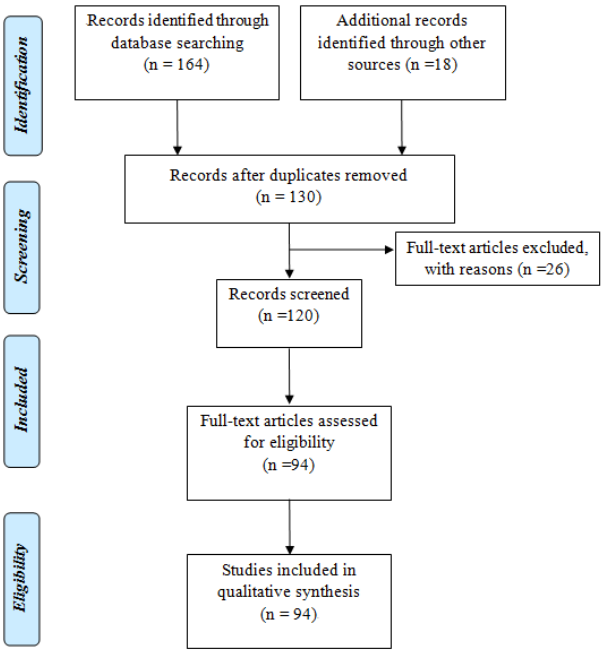


Figure 1. PRISMA process followed in the present study

(a) Records identified through the database:

• Specific key words such as, sustainable intensification, climate resilience practices, livestock based production system etc. were used for searching in database, and then the articles were selected that are focused on practices under sustainable intensification and climate resilient and production system simultaneously.

• Electronic literature was searched for capturing related peer-reviewed papers written and published in English in various peer-reviewed journals without imposing limits on publication year, afterward excluding the articles that are previous to the year 2000, and also those

articles which only focus on only one aspect such as sustainable intensification or climate resilience etc.

• Finally 164 articles were selected for further analysis (n=164).

(b) Records identified through other sources:

• Available unpublished thesis in https://krishikosh.egranth.ac.in/ (n=10).

• Annual reports of different institutes/universities, such as NDRI, FAO, IPCC, ILRI etc., working on climate change and its effect on the livestock production system (n=8).

(c) Duplicate records were removed.

• Screening of records: After removing duplicate articles or research, records were screened for the systematic review of concerned subjects (Figure 1).

• Exclusion of article: Articles of grey literature, like conference proceedings unrelated to social science, were excluded.

Eligibility: Remove the excluded articles after thoroughly screening these papers from a total number of screened records and enter the number as "full-text articles assessed for eligibility".

Included: Finally, the number of articles and records excluded during the eligibility step of full texts from the total articles reviewed for eligibility. In this present study a total of 94 were retained for review and further analysis.

Data tabulation, coding and analysis

Ninety-four final articles were imported into Nvivo12 and Voyant text analysis tools for archiving qualitative data summaries. The questions were prepared from selected article file and then imported to Nvivo12. After that the memos file (major key issues found out from the articles) was linked with concerned article file. Further, a list of data in different categories was developed as code and nodes for further analysis. Various key concepts are coded as 'nodes' for content analysis. Data summaries were created into words cloud and relative frequency count. Among all selected articles, qualitative data were drawn on the nodes as; 'resilient', 'impact', 'climate change', 'livestock production', 'vulnerability', 'sustainable intensification', and so on. Common findings were gathered through interactive visualizations.

A word cloud (Figure 2) shows the simple word frequency of a document in attractive visual form. The word presented commonly in the text appeared larger in the generated image. As the above figure depicted, the words such as 'production', 'livestock', 'sustainable', etc., appeared in most retrieved articles. Moreover, word cloud indicates that in present scenario sustainable intensification focused specifically on those practices which increase the production of our natural system sustainably.

Figure 3 indicates the relative frequency of keywords that appeared in the retrieved articles. The relative frequency highlights the importance of words over others. This qualitative data analysis validates the filtering process against our objectives. Those keywords we used for retrieving the articles are interrelated and relate to the main construct i.e., sustainable intensification and resilience against changing climate. The frequency of words in the selected article was used just to know the contents.



Figure 2. Words cloud of review articles

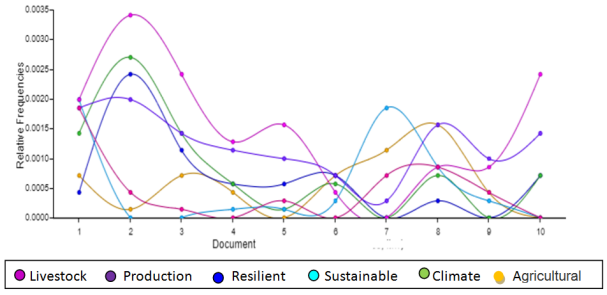


Figure 3. Graphs showing the relative frequency of keywords in review articles

Categorization of practices based on review article

According to the previously specified inclusion criteria, the whole of the material that was collected in the first stage was evaluated for relevance, including (a) related subjects (types of livestock production system specific to the country); (b) intervention use as sustainable intensification (c) effects on livestock production systems (impacts on systems); (d) type of strategies (as adoption, mitigation); (e) conclusion (researches considering the impacts/benefits on ecosystems, human health and economic loss). These techniques are widespread, may be region-specific, and may be connected to unique local agricultural circumstances (Wall and Smit, 2005.; FAO, 2013). For instance, the author identified various ecosystem-based practices based on systems adopted in different areas for sustainable intensification. The list of sustainable intensification strategies for the livestock industry may continue since various groups are in charge of diverse ecosystems. To understand and rationalize the results of the systematic review, the concerned practices were classified based on two aspects, i.e., practices followed under different forms of sustainable intensification and resilient climate livestock production practices (intensive production systems practices for livestock and land-based livestock) and finally all practices discussed in scenario of sustainable intensification (Table 1).

Table 1. Categorization of practices under sustainable intensification and climate resilient livestock production system

Construct	Categories	Practices	Number of articles covering mentioned practices	Type of strategies
Sustainable Intensification	Genetic Intensification	Higher yield fodder variety	12	Adaptation
		Improvement in nutrition	15	Adaptation and Mitigation
		Resilient animal breeds	9	Adaptation and Mitigation
	Ecological Intensification	Agroforestry	18	Adaptation and Mitigation
		Silvopasture	7	Adaptation and Mitigation
		Green manuring	9	Mitigation
		Organic farming	13	Mitigation
	Socio-economic Intensification	Creating farmers-friendly input and output markets	8	Adaptation and Mitigation
		Social capital constructions	16	Mitigation
		Human capital constructions	11	Mitigation
Climate Resilient Livestock Production	Land-based system	Agroforestry	7	Adaptation and Mitigation
		Grazing management	21	Adaptation and Mitigation
		Pasture management	13	Adaptation and Mitigation
	Intensive system	Animal breeding	6	Adaptation and Mitigation
		Animal herd management	13	Adaptation
		Feeding management	18	Adaptation
		Animal health management	13	Adaptation and Mitigation
		Early warning system	7	Adaptation and Mitigation
		Manure management	10	Adaptation and Mitigation
		Energy use efficiency	11	Mitigation
		Mixed farming	14	Adaptation and Mitigation

Results

Bibliographic data analysis

Among different countries, the United States (16%) had the maximum article publication, followed by the United Kingdom (14.65%), and India (11.23%) dominated the studies. As per the publication of the article concerned, scientific focus increased on the concerned subject from 2005 onwards (Figure 4).

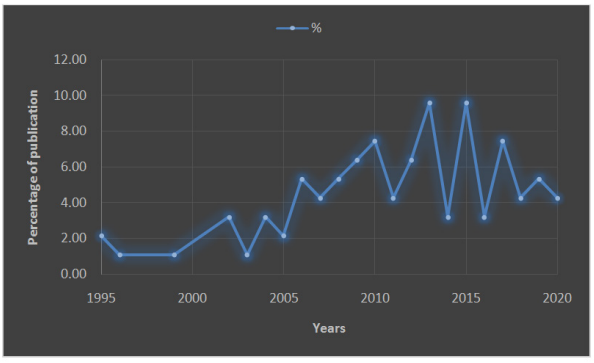


Figure 4. Review articles retrieved by publication year

The system covered under study

36.34 per cent of total publications were studied on an integrated farming system in which agriculture, livestock and other sectors are discussed in respect to resilient climate practices and their application, followed by intensive crop (24.3%), intensive livestock farming (20.7%) and land-based livestock system (18.66%) (Figure 5).

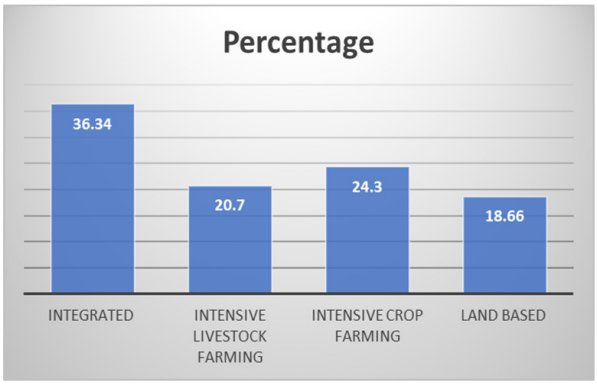


Figure 5. Type of systems covered under review articles

Systematic review analysis

In general terms, sustainable intensification combines genetic, ecological and socio-economic intensification. Among them are two technological approaches, i.e., ecological and genetic intensification (farm animal breeding). Along with that, socio-economic intensification is another approach that supports adopting technology and developing markets for products with sustainable intensification (Montpellier Panel, 2013).

Different forms of intensification and livestock production systems

Three pillars for ecological (agricultural system modified by farmers known as agroecosystem (Conway, 2012), to maintain the ecology) intensification (Cassman, 1999) were suggested as: "growth in yield potential", "improving or maintaining soil quality", and "efficient

and effective use of inputs and minimum loss of inputs to the surroundings by precision farming" which can be achieved by optimizing the management on field level with the help of site-specific data on weather. Regarding crops, pests, and weeds, the immense variety of wildlife is limited to a small number of species. However, inside the field boundaries, most of the basic biological processes continue to exist and may be employed extensively for creating sustainable types of farm animal production. At the same time, the accumulation of advantageous genes in breeds and variations is referred to as a genetic intensification process. Since molecular and cellular revolution of previous century, methods of biotechnology, such as genetic engineering, tissue culture, and marker-assisted selection, have been added to traditional breeding to strengthen the process further. Modern breeding techniques such as genetic intensification can contribute to sustainable intensification for increasing yields, qualifying the nitrogen fixation and uptake, enhancing nutrition and improving resilience to drastic changes in climate and diseases. However, socio-economic intensification helps the farmers get knowledge and acceptance of varied techniques via creating creative and long-lasting institutions on farm, in a community, and across all areas of a country. This includes enhancing the supportive environment, social and human capital and sustainable livelihoods. Smallholders need assistance entering profitable value chains and fair access to input and product markets. Investments in livestock extension and research, infrastructure like roads connecting farmers with the market, and construction of improved rural services, including health care and education access for everyone, will be necessary to increase productivity on existing land.

Although Seré and Steinfeld (1996) classify livestock production systems as either livestock systems or mixed farming systems, more than 90% of the dry matter given to animals (less than 10% production from non-livestock farming activities) in exclusively livestock systems comes from rangelands, annual forages, commercial feeds, and pastures (less than 10% of the value of produce is attributable to non-livestock agricultural activities). Furthermore, grassland-based and landless livestock production systems are the categories used to classify the sole livestock systems (landless monogastric systems and landless ruminant systems). The two types of mixed agricultural systems are irrigated and rain-fed systems. It is anticipated that the mixed agricultural systems and livestock systems based on grazing would be more impacted by climate change.

By improving feed digestibility and removing carbon dioxide via soil carbon sequestration, land-based systems (grazing based livestock production systems) reduce enteric methane emissions. However, various climate-smart and resilient options were also present for the intensive systems. These choices mostly deal with enteric fermentation and manure management (UNFCCC, 2011; Gill et al., 2009).

Practices followed in sustainable intensification as climate resilient livestock production system practices

Higher yields fodder variety

Variety such as Co.CN4 hybrid Napier grass (Tamil Nadu Agricultural University, Coimbatore, India), Bajra-Napier Hybrid (ICAR-Indian Veterinary Research Institute, Bareilly Utter Pradesh, India) etc., varieties were developed as high yielding varieties for capturing the benefits of the yield of one and adaptive benefits of other fodders. However, conventional methods of cattle breeding (*Bos taurus*) of temperature in West Africa, North Asia and Europe with Asian and African cattle of semi-arid and arid areas like the humped zebu cattle (*Bos indicus)* have also benefitted from improved yields and sustainability.

Improvement in nutrition

Poor people often consume basic staple foods such as maize, wheat, cassava, rice, sorghum, and millet, typically low in micronutrients like vitamin A, zinc and iron, to prevent malnutrition. While home gardens may produce more nutrient-dense meals that are high in micronutrients, another potential strategy is biofortification, breeding crops with increased nutritional value. Because beta-carotene is absent from the endosperm of rice grains, scientists are introducing new rice cultivars with modified variants of the crucial maize *psy* gene to increase the beta-carotene content to 31 µg/g (Montpellier Panel, 2013). In the Philippines and India, this novel "Golden Rice" has already evolved into regionally suitable varieties, and it is anticipated that more nations will have access to it in the next years. Contemporary breeding techniques may create new crop types and animal breeds that are high-yielders resistant to various climatic stress and shock. Breeders are increasingly skilled at fusing these many qualities into a single animal or seed.

The main challenge is to confirm the availability and affordability of new seeds and animals with appropriate biosafety regulations, providing corresponding inputs and appropriate extension advice or services.

Resilience animal breeds

Breeds of livestock often have built-in defenses against illnesses, pests, and climatic conditions native to the areas where they were developed. They encounter new pests and viruses that might be disastrous when they relocate to other areas. Narmada Nidhi (Nanaji Deshmukh Veterinary Science University, Jabalpur, Madhya Pradesh, India) is the chicken bred by crossing the Kadaknath native chicken breed with Jabalpur colour broiler, developed for free range scavenging in the backyard and semi-intensive rearing systems. They look similar to native chickens but have greater growth and output capacity. *Narmada Nidhi* birds thrive well with early sexual maturity (Yadav et al., 2017) and adapt to harsh climatic circumstances and were preferred by the farmers in tribal-remote regions.

Agroforestry

An intercropping of annual non-woody crops with scattered perennial trees or bushes. Usually, the deeper-rooted trees will take advantage of water and nutrients unavailable to the crops. The bottom cover of crops suppresses weeds and avoids erosion, whilst the trees might also provide mulch and shade, creating a microenvironment. Agroforestry is crucial for mitigating climate change because it can trap carbon in the soil. Additionally, it may improve the diet's quality, lowering enteric methane emissions. Agroforestry is a method of adapting to climate change because it increases a system's resistance to climatic unpredictability by intensifying and diversifying output using trees. Animals are less stressed by the heat and are more productive when shade trees are present. *Leucaena* leaves may significantly increase farm revenue by quadrupling weight growth per day, reducing production of methane per kilogram of milk and meat by a factor of 4 and 2, respectively, and doubling milk production per day in dairy cattle (Thornton and Herrero, 2010). Using trees for agroforestry may also boost carbon sequestration (Albrecht and Kandji, 2003).

Silvopasture

Like agroforestry, trees are planted alongside grasslands and other types of forage on which cattle graze (trees are cultivated on grazing land), allowing carbon to be stored both above and below ground. The combination of crops, shrubs, and grass frequently support livestock mixed farming. In semi-arid locations, agro-sylvo-pastoral systems provide a workable solution for safeguarding the region's fragile soils. Trees with multiple benefits preserve the soil, support the production of energy and animals, and sequester carbon that would otherwise enter the atmosphere as carbon dioxide.

Green manure

Legumes are grown alongside other plants to fix nitrogen and are subsequently incorporated into the soil to help a crop thrive. Green manures include the fern Azolla and Sesbania, containing N-fixing blue-green algae. Azolla is rich in vital amino acids, vitamins, minerals, and carotenoids and includes 25–35% protein by dry weight (Ivan and Thuget, 1995) and can be used as a feed resource (Alalade and Iyayi, 2006).

Organic farming

Many technologies mentioned above are combined in the extremely sustainable agricultural and animal production method known as organic farming. Returning organic matter to the soil improves soil quality and the soil biota. Other advantages include biological pest management (and minimal use of naturally occurring pesticides), mechanical or manual weed control, and utilizing important nutrients (N, P, and K) from leguminous crops, manures, and other renewable sources. In general, it will lead to a decrease in greenhouse gas emissions, particularly nitrous oxide. However, the ability to scale up and intensify organic agricultural yields enough to guarantee widespread societal food security remains a crucial challenge. A careful study of several additional tests reveals that the usual ratio of wheat yields, organic and conventional, is 0.65, meaning that organic production produces 30–40% less. This ratio is also same in case of other crops (Goulding et al., 2011). For developing nations, this ratio can be an underestimation. Converting to organic farming in drought-affected regions and under subsistence circumstances may increase yields when the soils have deteriorated over time, provided that there is an adequate local source of manure and compost and that there is access to extension services.

In conclusion, ecological intensification has a lot of potentials, at least in terms of resilience and sustainability, but it may not be able to provide the greater yields that intensification demands. These technologies are seldom used on a large scale because they often need a lot of labor and expertise. Therefore, although agricultural ecology is essential for enhancing sustainability, crop and animal breeders also play a significant role.

Creating farmer's friendly input and output markets

To enable the environment by developing efficient, effective, transparent, and fair input and output markets that are suitable for all small to large farmers. Markets play a key role in reducing poverty; poor farmers get a higher income for their work, uplifting them and their families out of poverty only through sustainable access to markets. Apart from that, most underprivileged farmers are not connected to markets. Markets are changing due to various variables, like urbanization, population expansion, rising per capita incomes, changing consumer choices, modernization of the food manufacturing and retailing industries, and advancements in the transportation and communications infrastructure. Additionally, huge, global agri-food firms are increasingly sourcing their raw materials from farmers in developing nations. Agricultural produce markets now provide a wide range of extremely differentiated products, from small village marketplaces that sell produce grown locally and use staple crops to the global market selling out-of-season, packaged vegetables. Such a range in different markets opens new possibilities for small-scale farmers. However, it also poses high risks with new and challenging obstacles to overcome.

A useful solution for this problem is the creation of "grain banks" for the deposit of grain at the village level owned and operated by a farmer organization. Another example, in Kenya, a national network of small and big markets assisted using KACE ("Kenya Agricultural Commodity Exchange"), a private sector corporation that offers accessibility of produce prices as well as other market intelligence to smallholder farmers via SMS ("Short Message Service") through mobile phone (Montpellier Panel, 2013). As effective, fair, and transparent output markets are essential for smallholders, the landless live-

stock process depends on purchasing various inputs and selling output. The price volatility of key inputs, particularly feed and energy, has risen due to climate change, which raises the "financial" risks for those participating in the animal supply chain. This is particularly true when input stocks level is maintained to a minimum across the "supply chain", and alternatives for absorbing price increases are restricted.

Furthermore, landless programs that primarily depend on transportation inside the supply chain may be rapidly impacted by the shifting disease patterns caused by global warming. Resilience may be attained by allowing supply networks to resolve the crisis or setting up the framework for rapid recovery following the crisis. Even though the limited experience was not advanced in this field, better coordination between the various supply chain participants, insurance programs, increased buffers, and larger stocks might help supply networks that depend on intensive livestock systems (FAO, 2017).

Social capital construction

Social cohesion is critical for a prosperous society and its sustainable development. In general, social capital refers to the positive experiences of individuals working and interacting with one another, such as farmers interacting with people from different research institutes and government officials. They develop connections based on solidarity and trust to attain group action and collaboration for the common good. In this situation, farmer organizations use economies of scale to minimize risk and increase group earnings.

Human capital construction

The foundation of sustained socio-economic intensification is the growth of smallholder farmers' human capital. Expanding skills, information, and experience arise via formal education and imparting knowledge distribution. In low-income nations, the social return rate for basic education is relatively high (approximately 23 per cent), and an increase in knowledge may boost labor productivity and wages. However, human capital is highly reliant on efficient institutional arrangements and impediments related to gender or ethnicity. Women's education is essential in creating human capital for the community. Apart from all these practices mentioned above, practical training and development of markets linkages on the preparation of primary and value-added livestock products (like preparation of Butter, Ghee, Dahi, Paneer, etc.) help especially women farmers to enable income generation activity in women hand as well as a community reaching towards food security.

Grazing management

Together with improved grassland productivity, adaptation and mitigation benefits got by grazing management. However, soils, climatic conditions, plant species, and grazing practices influence grazing management (Smith et al., 2008). Strategies under grazing management are as follows.

As the name indicates, rotational grazing is where the timing and frequency of grazing are altered with the livestock needs and pasture availability. This improves the forage's quality and digestibility, boosts the system's production, and lowers methane emissions each unit of live weight growth (Eagle et al., 2012). For example, grassland degradation in Northern China is mainly due to early grazing of summer pastures, whereas postponing grazing till "grass sprouts" have achieved a more progressed stage of development is a crucial sustainable grazing technique. Additionally, mobility of livestock was increased (a conventional technique of transhumant herders and nomadic) in several regions of Africa to match animal production demands with shifting rangeland supplies, which substantially enhanced the adaptability of livestock systems to climate change (drought in specific). Further, soil carbon sequestration as a technique of halting land or rehabilitating degraded areas may provide the most obvious mitigation advantages, which include a reduction in grazing pressure (Conant and Paustian, 2002). In these instances, animals may choose more nutrient-dense fodder because they have more alternatives, which is related to quicker rates of live weight gain when there is less grazing pressure, which may also result in lower intestinal emission intensities (Rolfe, 2010). These actions may improve damaged grassland soil health and water retention, strengthening the grazing system's resilience to climate change.

Animal breeding

Breeding productive animals is one method to enhance productivity and hence reducing the methane emission levels. Generally, climate change (breeding tract of Murrah buffalo) may increase the frequency of crossbreeding schemes that utilize locally adapted breeds resistant to diseases and parasites and heat and poor nutrition (Hoffman and Vogel, 2008). Changing the species of livestock may help promote adaptation to climate change. It is possible to achieve a certain output level with fewer nutrients by breeding more productive animals. This is an effective method for reducing greenhouse gas emissions. A more effective animal would retain more nitrogen from its diet through protein, and its feces and urine will contain less nitrogen (Gerber et al., 2013). Over the last 20 years, broiler genetic advancements in daily increase and feed conversion have significantly decreased emissions per unit of weight (Williams and Speller, 2016).

Animal herd management and disease control

Land-based livestock production systems have a variety of alternatives for managing their animals and herds that may boost feed conversion effectiveness, increase animal productivity, and, therefore, lower enteric emission intensities. Increased reproduction rates, a reduction in mortality, and a reduction in the slaughter age may result from improving animal husbandry through practices

that provide proper nutrition and appropriate feeding and reproductive techniques, routinely maintain animal health, and responsibly use antibiotics. For a certain emission level, all of these activities will boost output production. These acts most likely have little impact on adaption.

The management of illnesses could become more critical due to climate change, which may cause a rise in the growth of gastrointestinal parasites, additionally to managing animal performance to preserve and promote animal health (Wall and Morgan, 2009).

Animal feeding

With more frequent environmental variability (e.g., more occurrences of drought, heat, and cold waves), there could be a rise in the number of times when forage supply is insufficient to meet animal needs. Supplemental nutrition is often a key adaptation technique in these circumstances. Feeding practices such as providing enough green fodder to high yielding cattle during the cooler periods of the day and the feeding may be divided into 4 numbers instead of two, and feeding of bypass protein and fat to high-yielding dairy animals help towards getting resilient. Decreasing the amount of feed needed, i.e., improved feed efficiency per unit of output (such as milk or beef), can lower "greenhouse gas emissions" and boost farm income. Feed efficacy may also be raised by producing breeds that develop more rapidly, are hardier, gain weight more rapidly, or give more milk. Feed efficacy may also be raised by enhancing herd health via preventive health initiatives, better veterinary services, and enhanced water quality. Shifting to feed resources such as crop by-products and co-products from the "agri-food" sector is also a low-carbon footprint towards reduced emissions. Techniques like grinding and chopping straws, ammonia treatment of feed and straw residues, and urea molasses blocks will help in a 10–20 percent increase digestibility compared to unprocessed straw. Feed residues, and ultimately a 10 percent reduction in methane production. Ionophores like monensin hinder the development of gram-positive bacteria by decreasing the quantity of hydrogen accessible to methanogenic bacteria. Ruminal methane production is decreased by 30 percent by monensin treatment. Feed supplemented with yeast culture was demonstrated to enhance milk production in cattle and growth rates in sheep and cattle. Yeast culture supplementation resulted in a reduction of methane production by 20–25 percent.

Animal health management

The U.K. examined cost-effective methods to decrease "greenhouse" gas emissions by enhancing cattle health in their recent study. According to this research, cow illnesses may raise greenhouse gases released into the atmosphere by up to 113 percent per unit of the beef carcass and 4% of every unit of milk produced (Williams et al., 2015). An illness that temporarily impairs feed consumption or digestion results in a reduction in the rate of growth, which requires more time and effort to accomplish the same goal. Some practices are listed here as those implemented in livestock farms for creating resilient systems, such as the use of supplementation of vitamin E and selenium per day throughout the year or during milk production, follow-up deworming and vaccination of livestock, and supplementation of the essential mineral mixture, vitamins in non-pregnant anestrous animals (mainly in cattle), etc.

Early warning systems and insurance

Utilizing meteorological information to assist rural people in managing the risks brought on by unpredictable rainfall is an efficient preventative technique for dealing with climate change. It applies to all systems, but notably land-based systems, which are more prone to production failures and heavily dependent on the availability of local feed. But there are issues that need to be addressed about how well-suited climate forecasts are for managing cattle (Hellmuth et al., 2007). Various drought-prone areas of northern Kenya are testing indexed insurance schemes based on "satellite images" (Barrett et al., 2008; Mude, 2009). When an index value exceeds a certain level, farmers get a prompt, effective payout. Weather forecasting services like the provision of advisory services based on climate (rainfall, heatwaves, cold waves, temperature-humidity index (THI)) help the small farmers to take timely action in light of climate variability. Therefore, climate variability in terms of humidity patterns, rainfall, temperature, and severe weather phenomena like droughts, heatwaves, and floods are crucial markers for tracking and forecasting the prevalence of animal illnesses.

Improved waste/manure management

Options for manure management mitigation have a high potential in systems without access to land but a limited potential in systems with access to land. The majority of "methane emissions" from manure are produced by pigs, dairy cows, and beef feedlots, where dung is stored in anaerobic conditions and production is carried out on a large scale. Options for reducing greenhouse gas emissions include installing biogas collectors on covered manure storage facilities to trap methane. When compared to conventional manure management systems, the collected methane may be vented or utilized as a source of energy for heating, lighting, or electric generators, while digestate is used as fertilizer, and greenhouse gas emissions are reduced by higher than 30% (Battini et al., 2014). Removing manure to a storage facility at a frequent time interval with a regular scraping of manure is an effective practice to reduce greenhouse gas emissions. The separation of solid and liquid manure (centrifuge or filtering process) has a greenhouse gas mitigation potential of more than 30 percent (Montes et al., 2013).

Improving energy use efficiency in livestock farms

Landless systems generally need more "fossil fuel" energy than integrated livestock planting and harvest-

ing systems (FAO, 2009; Gerber et al., 2011). Energy is needed at several stages, including for manufacturing a variety of feedstuffs, water consumption, and modern cooling systems (such as sprays, foggers, or fans that cool the animals). This greatly protects the high-output animals used in landless systems from the negative effects of high temperatures. Gains in energy consumption efficiency are highly possible in the dairy sector. All energy-saving technology that could lower the amount of energy used in the system may lower greenhouse gas emissions, particularly in nations where the energy industry produces many emissions.

Mixed farming

In these systems, farmers may boost the profitability and sustainability of crop and animal production in addition to avoiding risks by producing a variety of commodities. Utilizing perennial fodder trees as well as high biomass fodders (such as sugar cane) and establishing fodder hedgerows along the contour offer great erosion control and must be established practices.

Climate-resilient practices in the livestock production systems are becoming a booming topic. And appears as it emerges a package to maintain food demand in the scenario of climate uncertainty. All interventions under climate resilience are considered as the practices of sustainable intensification (Sahu et al., 2020). This necessitates action needed for poor and marginal farmers who are resource-poor and are most affected by climate change with the least contribution towards it so that developing countries must increase their food security and speed up economic growth. Moreover, sustainable intensification complements the climate-resilient livestock production systems in terms of higher yield, and productivity including climate adaptation, mitigation, and food security (FAN, 2020).

Conclusion

In terms of climate resilience, the sustainable intensification may be important as a novel model for farmers as long as appropriate, adequate resources and practices are assisted and supplied at all scales. Success may often be obtained on a small scale, such as a piece of farm or land, but sometimes just one or two of the economic, social, and environmental goals are achieved. Various problems or barriers are faced by the small farmers towards sustainably intensifying their production, incomes, and nutrition. Apart from rights to land for both women and men, higher output, more accessible capital investment (either on a massive scale or via microcredit), available labor, improved skills, knowledge, and access to both input and output markets are all necessary conditions for intensification. Approximately 80% of the economic losses caused by environmental deterioration are attributable to improper management of nutrients. On the other hand, nutrient management improvements are one of the most affordable strategies to achieve sustainable intensification and climate resilience while enhancing farm-scale economics and resource utilization at the national level. The Sustainable Intensification concept offers the way ahead. Specifically focused financial investments and public-private partnerships, research into pertinent technological and socioeconomic advancements, and active participation by small farmers in the process, and, most all, political leadership are required.

Ethical approval

The author (with all co-authors) declared that the manuscript was not submitted to more than one journal for consideration at the same time. The submitted review article was original and has not been published elsewhere in any language or form. Results were provided in a clear, truthful manner without the use of improper data manipulation. Authors followed discipline-specific guidelines for collecting, evaluating, and processing data.

Consent to publish

The author (Ruchi Singh) takes responsibility for releasing this content on behalf of all co-authors and signs the release form on their behalf.

Authors' contributions

Each author contributed to the conceptualization and design of the study. Data collection, material preparation, and analysis were carried out by Ruchi Yadav. The methodology was written by Ruchi Singh and Sanjit Maiti. The initial manuscript draft was prepared by Ruchi Singh, and other contributors provided feedback on earlier versions. The final document was reviewed and approved by all authors.

Conflicts of interest/competing interests

Ruchi Singh, on behalf of all authors, declares that they have no conflict of interest regarding this review paper. The authors give big thanks to the National Dairy Research Institute, Karnal, India, for the given scientific environment to write on the subject materials or matter covered in this document. The scholars have no proprietary or financial interests in any content covered in this paper.

References

Alalade O.A., Iyayi E.A. (2006). Chemical composition and feeding value of Azolla (*Azolla pinnata*) meal for egg-type chicks. Int. J. Poultry Sci., 52: 137–141.

Albrecht A., Kandji S.T. (2003). Carbon sequestration in tropical agroforestry systems. Agric. Ecosyst. Environ., 99: 15–27.

Barrett C.B., Carter M.R., McPeak J., Mude A. (2008). Altering poverty dynamics with index insurance: Northern Kenya's. Madison, USA, University of Wisconsin.

Battini F., Agostini A., Boulamanti A.K., Giuntoli J., Amaducci S. (2014). Mitigating the environmental impacts of milk production via anaerobic digestion of manure: a case study of a dairy farm in the Po Valley. Sci. Total Environ., 481: 196–208.

Beroya-Eitner M.A. (2015). Ecological vulnerability indicators. Ecol. Indic., 60: 329–334.

Cassman K.G. (1999). Ecological intensification of cereal production

systems: yield potential, soil quality, and precision agriculture. Proc. Natl. Acad. Sci., 96: 5952–5959.
Conant R.T., Paustian K. (2002). Soil carbon sequestration in overgrazed grassland ecosystems. Global Biogeochemical Cycles., 16: 1143.
Conway G. (2012). One billion hungry: Can we feed the world? Ithaca: Cornell University Press.
C2ES (2019). What is climate resilience and why does it matter?. Climate Essentials, 4: 1–12.
DFID (2013). Sustainable development: A review of monitoring initiatives in agriculture.
Eagle A.J., Olander L.P., Henry L.R., Haugen-Kozyra K., Millar N., Robertson G.P. (2012). Greenhouse gas mitigation potential of agricultural land management in the United States: a synthesis of literature. Report N.I. R 10-04. 3rd ed. Durham, USA, Nicholas Institute for Environmental Policy Solutions, Duke University.
Fan S. (2020). Sustainable intensification of agriculture is key to feeding Africa in the 21st century. Front. Agr. Sci. Eng., 7: 366–370.
FAO (2012). Livestock sector development for poverty reduction: an economic and policy perspective – Livestock's many virtues, by J. Otte, A. Costales, J. Dijkman, U. Pica-Ciamarra, T. Robinson, V. Ahuja, C. Ly and D. Roland-Holst. Rome, pp. 161.
FAO (2013). Climate-Smart Agriculture – Sourcebook, The U.N. Food and Agriculture Organisation FAO: Rome, Italy, p. 557. Available online: http://www.fao.org/3/a-i3325e.pdf accessed on 21 December 2020.
FAO (2017). http://www.fao.org/climate-smart-agriculture-sourcebook/production-resources/module-b2-livestock/chapter-b2-3/en/
FAO (2009). State of food and agriculture – livestock in the balance. Rome.
FAO (2012). The state of food insecurity in the world, Save and grow. A policymaker's guide to the sustainable intensification of smallholder crop production. FAO, Rome, pp. 102–140. http://www.fao.org/ag/save-and-grow/
FAOSTAT (2013).
Gerber P., Vellinga T., Opio C., Steinfeld H. (2011). Productivity gains and greenhouse gas intensity in dairy systems. Livest. Sci., 139: 100–108.
Gerber P.J.H., Steinfeld B., Henderson A., Mottet C., Opio J., Dijkman A., Falcucci G.T. (2013). Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Rome: FAO. Available from http://www.fao.org/3/a-i3437e.pdf.
Gill M.P., Smith P., Wilkinson J.M. (2009). Mitigating climate change: the role of domestic livestock. Animal, 43: 321–322.
Goulding K., Trewavas A., Giller K. (2011). Feeding the world: a contribution to the debate. World Agricult., 2: 32–38.
Hellmuth M.E., Moorhead A., Thomson. M., Williams J. (2007). Climate risk management in Africa: learning from practice. Climate and Society. No. 1. Palisades, NY, the International Research Institute for Climate and Society IRI. http://www.livestockglobalalliance.org/. The livestock sector is vital to global food security and health. accessed 13 January 2021.
Herrero M., Thornton P.K. (2013). Livestock and global change: Emerging issues for sustainable food systems. Proc. Nat. Acad. Sci., 110: 20878–20881.
Hoffman M.T., Vogel C. (2008). Climate change impacts on African rangelands. Rangelands, 30: 12–17.
Hurst P., Termine P., Karl M. (2005). Agricultural workers and their contribution to sustainable agriculture and rural development. Rome, FAO.
IPCC (2013). Summary for policymakers. In: Climate change: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change, Stocker T.F., Qin D., Plattner G.K., Tignor M.M.B., Allen S.K., Boschung J., Nauels A., Xia Y., Bex V., Midgley P.M. (eds). Cambridge University Press, p. 154.
Ivan D.T., Thuget T.Q. (1995). Use of Azolla in rice production in Vietnam. In: Nitrogen and Rice. International Rice Research Institute, Philippines, 395.
Jabareen Y. (2013). Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. Cities, 31: 220–229.
Kissinger M., Rees W.E. (2010). An interregional ecological approach for modelling sustainability in a globalizing world – reviewing existing approaches and emerging directions. Ecol. Modelling, 22121: 2615–2623.
Kumar S., Lakhran H., Meena R.S., Jangir K.C. (2017). Current needs of sustainable food and forage production to eliminate food and forage insecurity under climate change era. Forage Res., 43: 165–173.
Kuyper T.W., Struik P.C. (2014). Global food security, rhetoric, and the sustainable intensification debate. Curr. Opin. Env. Sust., 8: 71–79.
Maia A.G., Miyamoto B.C.B., Garcia J.R. (2018). Climate change and agriculture: Do environmental preservation and ecosystem services matter? Ecol. Econ., 152: 27–39.
Moher D., Liberati A., Tetzla J., Altman D.G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann. Intern. Med., 151: 264–269.
Montes F., Meinen R., Dell C., Rotz A., Hristov A.N., Oh J., Waghorn G., Gerber P.J., Henderson B., Makkar H.P. (2013). Special topics – mitigation of methane and nitrous oxide emissions from animal operations: II. A review of manure management mitigation options. J. Anim. Sci., 91: 5070–5094.
Mude A. (2009). Index-based livestock insurance for northern Kenya's arid and semi-arid lands: the Marsabit pilot. Project document. ILRI, Nairobi, Kenya. pp. 14.
Popp A., Lotze-Campen H., Bodirsky B. (2010). Food consumption, diet shifts and associated non-CO_2 greenhouse gases from agricultural production. Global Environ. Change, 20: 451–462.
Pretty J., Toulmin C., Williams S., (2011). Sustainable intensification in African agriculture. Int. J. Agricult. Sust., 9: 5–24.
Rockström J., Steffen W., Noone K., Persson A., Chapin F.S., Lambin E., Lenton T.M., Scheffer M., Folke C., Schellnhuber H., Nykvist B., De Wit A., Hughes T., Van der Leeuw S., Rodhe H., Sörlin S., Snyder P. K., Costanza R., Svedin U., Falkenmark M., Karlberg L., Corell R.W., Fabry V.J., Hansen J., Walker B., Liverman D., Richardson K., Crutzen P., Foley J. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecol. Soc., 142: 32–39.
Rolfe J. (2010). Economics of reducing grazing emissions from beef cattle in extensive grazing systems in Queensland. Rangeland J., 32: 197–204.
Sahu G., Rout P.P., Mohapatra S., Das S.P., Pradhan P.P. (2020). Climate smart agriculture: a new approach for sustainable intensification. Curr. J. Appl. Sci. Technol., 39: 138–147.
Seré C., Steinfeld H. (1996). World livestock production systems: current status, issues and trends. FAO Animal Production and Health Paper, Rome, 127.
Smith P., Martino D., Cai Z., Gwary D., Janzen H., Kumar P., McCarl B., Ogle S., O'Mara F., Rice C., Scholes B., Sirotenko O., Howden M., McAllister T., Pan G., Romanenkov V., Schneider U., Towprayoon S., Wattenbach M., Smith J. (2008). Greenhouse gas mitigation in agriculture. Philosoph. Transact. Royal Soc., 363: 789–813.
Steffen W., Richardson K., Rockström J., Cornell S. E., Fetzer I., Bennett E. M., Biggs R., Carpenter S. R., DeVries W., DeWit C. A., Folke C., Gerten D., Heinke J., Mace G. M., Persson L. M., Ramanathan V., Reyers B., Sörlin S. (2015). Planetary boundaries: guiding human development on a changing planet. Science, 347.
The Montpellier Panel (2013). Sustainable Intensification: A New Paradigm for African Agriculture, London.
Thornton P.K., Herrero M. (2010). The potential for reduced methane and carbon dioxide emissions from livestock and pasture management in the tropics. PNAS, 107: 19667–19672.
UNFCCC (2011). Reducing vulnerability to climate change, climate variability and extremes, land degradation and loss of biodiversity: environmental and developmental challenges and opportunities, United Nations Framework Convention on Climate Change UNFCCC: Rio de Janeiro, Brazil, New York, NY, USA, pp. 47.
USDA United States Department of Agriculture (2013). Climate Change and Agriculture in the United States: Effects and Adaptation. USDA technical bulletin, Washington, DC.

Wall E., Smit B. (2005). Climate change adaptation in light of sustainable agriculture. J. Sustain. Agric., 27: 113–123.

Wall R., Morgan E. (2009). Veterinary parasitology and climate change. Vet. Parasitol., 163: 263.

Williams A., Speller D. (2016). Reducing the environmental impact of poultry production. In: Sustainable poultry production in Europe, Burton E., Gatcliffe J., O'Neill H.M., Scholey D. (eds). Oxfordshire UK, CABI.

Williams A.J., Chatterton G., Hateley A., Curwen J.E. (2015). A systems-life cycle assessment approach to modelling the impact of improvements in cattle health on greenhouse gas emissions. Adv. Anim. Biosci., 6: 29–31.

Yadav J., Mandal M.K., Singh R., Baghel R.P.S. (2017). Performance analysis of Narmada Nidhi poultry under backyard farming system in Mandla District of Madhya Pradesh. Indian J. Vet. Sci. Biotechnol, 13: 22–24.

Received: 23 IX 2022
Accepted: 15 II 2023