



## Agroecological principles and practices for the transition to sustainable cattle farming. Review



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### **Abstract:**

The development of the livestock sector is affected by environmental, economic, food, energy, sanitary, and migratory crises, all of which have an impact on people's food and health. These crises force producers to reflect and rethink the livestock breeding practices they apply within the sociocultural, environmental, economic, and political context. Sustainable cattle ranching makes it possible to face these crises by applying agroecological practice. The objective of this review is to analyze the agroecological principles and practices that promote a transition toward sustainability in the cattle sector. Both the impact of the civilization crisis on cattle raising and the perspectives and scope of agroecology were discussed with the aim of identifying the contributions of this discipline to the production of good-quality milk and meat accessible to society. It was concluded that agroecological principles and practices are universal and can be applied to cattle ranching in order to achieve

sustainable production systems. These principles and practices can be adapted to climate zones and reduce the impact that the civilization crisis has generated in cattle raising. These principles and practices should be applied according to the level, quantity, and quality of the resources of each dimension. The analyzed initiatives show that meat and milk are produced with the lowest possible inputs, a low environmental impact, and the formation of organized communities. Finally, their proper application depends to a large extent on the willingness, motivation, and empowerment of the producers.

**Keywords:** Agroecological livestock farming, Agroecology, Food Security.

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## Introduction

Internationally, cattle production is a very important activity for the economy of a variety of cultures. It not only is the work and sustenance for people living in rural and agricultural areas<sup>(1,2)</sup> but is considered a means to achieve food self-sufficiency. In recent years, the world has experienced crises of multiple dimensions: economic, environmental, social, energy, health, migration, etc. These crises have led to a larger one, defined as a civilizational crisis, which has a simultaneous impact on nature, land, food, and health. The great crisis has forced mankind to reflect and rethink its way of life<sup>(3,4)</sup>.

The development of sustainable livestock farming is an alternative to this crisis. Its vision is to have systems that are more durable over time and less polluting to respond to the existing demand to produce healthy food that will protect the environment and improve the quality of life of producers, in articulation with local and regional processes<sup>(5,6)</sup>. Sustainable production based on agroecological processes arises from the application of principles in the sociocultural, environmental, economic, and political dimensions<sup>(5,6)</sup>. These principles guide the spatial and temporal design of a production unit, in the development, integration, and application of technical-productive practices and ecological processes<sup>(7,8)</sup>. Agroecology is recognized in the action of a project that may transform the livestock sector by identifying actions that are differentiated and well-defined, and contribute to society<sup>(9,10)</sup>.

The objective of this review is to analyze the agroecological principles and practices that promote a transition towards sustainable cattle raising, through a bibliographic analysis, the

impact of the civilization crisis on cattle raising was discussed, as well as the perspectives of agroecology and its scope, with the purpose of identifying its contributions to achieve a better production of accessible and quality milk and meat for society.

### **The multiple crises in cattle farming**

Worldwide, cattle production is immersed in multiple crises, such as environmental, economic, food, energy, sanitary and migratory crises, due to industrialized livestock production driven by the capitalist economy and neoliberal policies<sup>(11)</sup>.

The Green Revolution model substantially increased crop and livestock production, but over time direct and indirect environmental impacts increased, such as overexploitation of the land, the presence of harmful pathologies (i.e. tick-borne diseases), nutritional deficiencies due to the reduction of net aerial biomass in pastures due to long periods of drought, and the reduction of the net aerial biomass in pastures due to long periods of drought<sup>(12)</sup>, depletion of soil fertility, soil and water contamination by agrochemicals, presence of invasive species, loss of agrobiodiversity, economic inequality, inequity in the distribution of wealth, and reduction of medium and long-term yields<sup>(3,4,13)</sup>.

Livestock producers face economic crises such as high input costs (for example, it costs more to produce 1 L of milk than companies are willing to pay), the use of powdered milk for the manufacture of dairy products, dependence on intermediaries, and the presence of large national and transnational companies that export milk and meat<sup>(14)</sup>.

Another crisis that has affected this sector is the food crisis. In this crisis, on the one hand, it is evident that, at a global level, there is a business expectation derived from the population growth that will exceed 9 billion inhabitants in 2050. Increased production of animal protein (e.g., milk, meat, eggs, and fish) will be needed in order to meet global demand, and according to FAO data, it is estimated that meat consumption will increase by 76 % by 2050, with a doubling of poultry consumption, a 69 % increase in beef consumption, and a 42 % increase in pork consumption<sup>(3,15,16)</sup>.

In contrast, international organizations such as the Food and Agriculture Organization of the United Nations (FAO) point out that there is a surplus in food production for the whole of humanity. Latin America alone produces 40% more food than it consumes<sup>(17)</sup>. According to the above, the real issue is the unequal distribution of these products and the lack of economic resources to acquire them, i.e., the lack of food safety. Thus, the issue is twofold: the capitalist

center and the impoverished world. From the above, conventional food production has turned food into a commodity, so that it is no longer regarded as an essential good for life<sup>(3,4)</sup>.

In addition to the above crises, the livestock sector is affected by the energy crisis, which refers to the exaggerated consumption of oil, with the consequent greenhouse gas (GHG) emissions and indiscriminate consumption of natural resources<sup>(18)</sup>. In most of these systems, the use of non-renewable energy from fossil fuels is evident, mainly of petroleum, which is the source of diesel, gasoline, and lubricants used in machinery and equipment, as well as in the manufacture of fertilizers, pesticides, and chemically synthesized herbicides. Gas is also used for heating<sup>(3,4,19)</sup>.

Cattle ranching brings with it a variety of rapidly increasing manifestations such as contamination of air and water, desertification, and loss of biodiversity; however, one of its most acute manifestations is linked to climate change<sup>(3,4)</sup>. It results in variations in temperature, decrease in precipitation, loss of biodiversity, land degradation, and water pollution, all of which are effects of climate change due to the strong pressure on natural resources<sup>(20)</sup>. It should be noted that the decrease in rainfall and water pollution directly affect cattle producers, as 6 to 15 L of water are needed to produce 1 kg of carcass meat, and 0.80 to 1 L of water is required to produce 1 kg of milk<sup>(21)</sup>.

On the other hand, more than 1,000 pesticides are utilized worldwide to prevent pests from destroying food<sup>(22)</sup>. Considerable amounts of pesticides that favor forage growth (such as glyphosate), insecticides, and fungicides (such as hexachlorobenzene) used in the storage and transport of seeds for forage purposes are being applied in livestock farming<sup>(23)</sup>. The chemical residues most frequently found in food of animal origin are pesticides, antimicrobials, antiparasitics, disinfectants, detergents, anabolics, and mycotoxins<sup>(24)</sup>. The World Health Organization (WHO) has identified the risks of pesticides in the increase of acute poisoning of people who apply them by the long-term adverse effects that these substances produce in them, derived from the level of exposure to them and from the presence of their residues in food<sup>(22)</sup>.

USDA data show that, in the U.S., the use of herbicides in 98 % of the hectares planted with soybean crops used as feed for cattle under an industrial production system<sup>(25)</sup>. The main herbicide applied is glyphosate, an active ingredient that destroys primary organisms and ecosystem food chains<sup>(26)</sup>. In the case of Mexico, there is already a final decree that establishes the gradual elimination of the use of glyphosate and genetically modified corn<sup>(27)</sup>.

It should be noted that the capitalist economy is largely responsible for the devastation of nature and the effects on the environmental crisis. For example, industrialized livestock caused about 26 % of the global land area to be deforested and converted to pasture, most of it in the tropical areas of developing countries<sup>(28)</sup>.

Likewise, in the health crisis, the existence of zoonotic pandemics such as Covid-19 has shown that the general population is not prepared to face emerging diseases. There is a high likelihood that these health crises will continue to emerge as pandemics are exacerbated by climate change and agro-industrial production of contaminated food<sup>(4)</sup>.

As is already known, the agricultural sector has been the most affected by the migratory crisis. Young, creative labor migrates to regions where it can find better opportunities and higher incomes<sup>(4)</sup>. Based on the above, it can confirm that all crises lead to a major crisis defined as a civilizational crisis, which forces to rethink the way people live, produce, and consume food. Living well is a worldview that includes human beings, animals, plants, minerals, stars, spirits, and divinities<sup>(9,29)</sup>. It is a way of existence that is in balance with all the elements of the earth; it is neither wealth nor poverty, but a life in harmony with all beings, an intercultural, interbiotic, and intergenerational coexistence<sup>(3)</sup>.

### **Agroecological perspectives**

The scientific discipline that studies agriculture and, today, the livestock sector as well, from an ecological perspective is called "Agroecology", and is defined as a theoretical framework whose purpose is to analyze agricultural and farming processes in an interdisciplinary manner, integrating agronomic, socio-cultural, environmental, economic, and political elements<sup>(30)</sup>.

Agroecology combines traditional knowledge (local ethnoscience on plants, animals, etc.) and knowledge from science. By integrating both types of knowledge, principles emerge that take different technological forms according to the place and depending on the sociocultural, economic, environmental, and political context. This integration should be derived from a participatory or transdisciplinary research process, led by the producers themselves<sup>(31)</sup>.

Globally, this approach shares the following characteristics: it is a science, a praxis, and a social movement; it applies ecological concepts, principles, and knowledge; it is based on the ecological processes of the agroecosystem; it is guided by bottom-up and regional processes; it seeks the co-creation of knowledge; it includes an explicit focus on the social and economic dimensions of food systems, and it uses a political economy approach<sup>(32)</sup>.

From the point of view of research, local, farmer, and indigenous knowledge is valued, vindicated, and rescued. From a sociocultural and economic perspective, participatory dynamics are generated from the interests of the producers themselves. From an environmental and productive viewpoint, it is to investigate a productive and empirical space.

And from the angle of social transformation, is integrate the previously mentioned perspectives and incorporate a new research process between the researchers and the reality under research<sup>(33)</sup>.

This approach has evolved from a scientific discipline to a social, cultural and political movement. However, its relationship with other hybrid disciplines (such as political ecology, ecological economics, environmental history, and ethnoecology) renders it a productive practice in opposition to industrial production, as well as a social movement linked to the vindication of small producer<sup>(34)</sup>.

Currently, in agroecology, certain promising initiatives not only include the production of goods, but go all the way to consumption, promoting short food supply chains for consumers, i.e. direct marketing schemes (cooperative-driven and farmer-promoted), exchange systems, and local sales<sup>(35)</sup>.

Agroecology contributes to improve the quality of life of producers by designing biodiverse agricultural systems that are energy efficient, conserve natural resources, and are resilient to climate change. However, certain NGO actors; ONU-FAO, government agencies, and academic institutions that use the term agroecology have used it interchangeably as sustainable intensification, regenerative agriculture, climate-smart agriculture, among others, without explaining its particularity<sup>(8)</sup>.

Food production systems consist of various elements, activities, and actors that interrelate in the production, transformation, distribution, and consumption of food<sup>(36)</sup>. In addition, they maintain and preserve natural ecosystems, providing valuable food supplements, construction materials, medicines, organic fertilizers, fuels, etc., which improve the nutritional status and livelihoods of small farmers. In this sense, agroecological interventions are effective in traditional systems, as they increase their production, income, food safety, and resilience to climate change<sup>(31,35)</sup>. Furthermore, agroecological design and management in a production unit in Cuba increased energy efficiency from 2.70 to 17.26, reducing energy costs and labor intensity per ha (730 h/ha/yr). In addition, the external dependency index decreased from 71.39 % to 1.81 %, and the yields of its rice (*Oriza sativa* L.), tobacco (*Nicotiana tabacum* L.), beans (*Phaseolus vulgaris* L.), corn (*Zea mayz* L.), and livestock (cows, chickens, and pigs) fed cassava (*Manihot esculenta* L.) and sugar cane (*Saccharum* sp.), increased from 4.18 t/ha/yr to 6.70 t/ha/yr, showing that agroecological practices increased productivity per unit of arable area and for the total area, generating greater energy efficiency and food for more people per ha<sup>(37)</sup>.

It is clear that agroecology does not promote technical recipes but principles, whereby one or more principles are linked to practices and processes that set ecological interactions in motion<sup>(38)</sup>. Agroecological practices seek to produce food through ecological processes and

ecosystem services, integrating them as elements in the development of practices<sup>(39)</sup>. Today, this systemic approach shows a different path by providing principles that allow the design of production and consumption systems<sup>(40)</sup>, where innovations are born *in situ* with the producers and adapted to the socio-economic situation<sup>(31)</sup>.

## **Agroecological principles and practices**

### **Sociocultural dimension**

Traditional agricultural systems have evolved over generations, where the social dynamics, skills, and traditions of the producers have been central aspects of the existing knowledge<sup>(41)</sup>. Agroecological principles for this dimension promote social and cultural activities that help producers meet their current and future needs<sup>(37)</sup>.

Principle 1 (Table 1) seeks to recognize the diversity of experiences to promote the collective exchange of knowledge. It is important for farmers to embrace the exchange of personal experiences and local knowledge between producers, between generations, and among members of an organization<sup>(42,43)</sup>. Local and indigenous producers contribute to the generation of experiences and knowledge, with the participation of women, elders, and community organizations<sup>(40)</sup>.

**Table 1:** Agroecological principles of the socio-cultural dimension

Principles	Reference
1. To recognize the diversity of experiences to promote the collective exchange of knowledge, skills, and local, traditional, empirical, and scientific innovations, through the exchange of knowledge between producers, and among the members of an organization together with alliances that give equal weight to the producer and researcher.	(7,41,43,44)
2. To enhance the organization of producers and actors with a view to the design of community and society under the idea of long term sustainability.	(43,45)
3. To build agroecosystems based on the social values of culture, identity, tradition, social and gender equity, and innovation in local communities in order to preserve the social fabric, maintain the spiritual relationship with the environment, and support healthy, diversified, seasonal, and culturally appropriate diets.	(43,45)
4. To create dignified livelihoods where there is respect for the diversity of gender equity, sexual orientation, race, and religion, in order to support women in leadership and equality among all stakeholders.	(41,43,44)
5. To ensure connectivity, geographic proximity and trust among stakeholders throughout the production, processing, and consumption phases, mainly with the inclusion of farmers, consumers, technical advisors and scientists in a collective network where certification alternatives such as Participatory Guarantee Systems and Community Supported Agriculture are promoted, in order to encourage solidarity and debate among people of diverse cultures and values, both rural and urban.	(41,43,44)

Principle 2 seeks to promote the organization of producers under the idea of sustainability. The permanence of the family in the production unit contributes to the organization necessary for production<sup>(37)</sup>. Moreover, in the rural community it is important to build social cohesion and generate greater interaction among stakeholders when making collective decisions to transform their lives and stabilize their commitments<sup>(46)</sup>.

Principle 3 refers to the construction of agroecosystems based on social values. Social equity is one of the social values based on the quality of life; livelihoods in rural areas; health of producers and consumers; equity in the control of land, economic power, and participation in all benefits<sup>(43,45)</sup>.

In cattle production, the work performed by women is to some extent invisible. Women not only are responsible for domestic work but they also engage in livestock breeding activities, are responsible for their home's backyard, and contribute significantly to the survival of the family. However, progress in social equity for rural areas remains fragile<sup>(47)</sup>.

Principle 4 seeks to create dignified livelihoods that bring well-being, abundance, and prosperity to all of society<sup>(37)</sup>. Where one can live free from oppression, in peace, and with enough time to meet the family's needs —with a quality of employment where wages are adequate to ensure a decent livelihood, covering the costs of food, education, clothing, medical care, recreation, and savings<sup>(48)</sup>. It is important to empower producers in the livestock sector so that they can have a dignified life<sup>(49)</sup>.

Principle 5 aims to ensure connectivity and the inclusion of a collective network of producers, consumers, and technical and scientific advisors, where certification is promoted through Participatory Guarantee Systems (PGS)<sup>(43)</sup>.

### **Environmental dimension**

In the face of the present-day environmental crisis, the environmental dimension in a production system is important as a means to reduce the environmental footprint caused by livestock farming, through ecological processes that may enhance its viability and stability<sup>(5)</sup>. In this dimension, management practices and processes for beef cattle production aim to reduce greenhouse gas (GHG) emissions; to promote proper water management, an appropriate increase in soil nitrogen content, and a reduction in the amount of non-recyclable materials; to minimize the use of veterinary drugs, and to meet all the needs of cattle<sup>(48)</sup>.

Principles 1 and 2 (Table 2) refer to increasing biomass recycling, and to securing, improving, and optimizing soil functioning, respectively. It should be noted that one of the most important indicators of healthy soil is organic matter<sup>(8)</sup>.

**Table 2:** Agroecological principles of the environmental dimension

Principles	Reference
1. To improve biomass recycling, with a view to optimizing organic matter decomposition, nutrient cycling, and the use of local renewable resources over time in agricultural and food systems.	(7,8,41,44,45)
2. To ensure, improve and optimize soil functioning, providing favorable conditions for plant growth, incorporating organic matter to promote biological activity.	(7,8,44)
3. To adopt management practices to improve animal health and welfare.	(5,7,44)
4. To value the health of the agroecosystem by strengthening its "immune system" through the enhancement of functional biodiversity and the creation of appropriate habitats.	(7,8,45)
5. To reduce the loss of energy, water, nutrients, and genetic resources by improving the conservation and regeneration of agrobiodiversity.	(7,8)
6. To maintain and improve the diversification of species and genetic resources in the farming system over time and space (farm, landscape, zone, etc.) in order to strengthen its resilience by adapting management practices.	(7,8,41,44)
7. To eliminate the use and dependence on external synthetic inputs of human origin such as herbicides for the control of pests and weeds that damage the environment and the health of the producer and consumer. It is better to manage pests, diseases, and weeds than to control them.	(41 45)
8. To increase positive ecological interaction, synergy, integration, and positive complementarity among agroecosystem elements.	(8,41,44)
9. To support the adaptation, biological and genetic potential of cultivable animal and plant species, for greater agroecosystem resilience.	(41,45)

An example of these principles is the use of legumes, as these plants increase the efficiency of manure and fix atmospheric nitrogen in the soil, as well as absorb large amounts of nitrogen in the system<sup>(50)</sup>. On the other hand, cattle grazing, incorporation of animal manure and cover crops are practices that increase the nitrogen content in the soil<sup>(45,48)</sup>.

Agroforestry allows the sustainable use of land and promotes the integrated management of trees, crops, and animals. Over the last 40 yr, it has proven to be a discipline that contributes to the improvement and development of sustainable agricultural systems<sup>(51)</sup>. Agroforestry systems have great potential to mitigate GHGs and sequester organic carbon in the soil

through residue conservation practices. It has been found that the use of silvopastoral practices can absorb and store between 42 and 90 picograms (Pg) of carbon from the atmosphere over a period of 50 to 100 yr<sup>(52)</sup>. In addition, silvopastoral systems are an option that provides important socio-cultural, environmental, and economic benefits for sustainable production<sup>(53)</sup>. It is possible to achieve good forest cover conservation through proper stocking rate management, in terms of the ratio of the number of heads of cattle to the grazing area and time<sup>(54)</sup>.

The introduction of legumes as fodder in tropical pastures increases soil carbon storage capacity, which ranges between 58.2 and 69.9 %, compared to livestock production in pastures. In addition, it has been demonstrated that the combination of grasses with white clover plants (*Trifolium repens*), banana trees (*Musa paradisiaca*), dandelion (*Taraxacum officinale*), and the integrated management of weeds, achieve higher concentrations of minerals<sup>(28,31)</sup>. Silvopastoral systems are a viable option to ensure the maintenance of environmental services and reduce methane emissions (CH<sub>4</sub>)<sup>(54)</sup>. In an evaluation carried out in silvopastoral systems, the average carbon sequestration was found to be of -26.27 Mg·CO<sub>2e</sub> ha<sup>-1</sup> (the negative sign refers to carbon sequestration), exceeding the average enteric CH<sub>4</sub> emissions of 23.54 Mg·CO<sub>2e</sub> ha<sup>-1</sup> (the positive sign refers to carbon emission), which indicates a net balance of -2.73 Mg·CO<sub>2e</sub> ha<sup>-1</sup> of carbon removed from the atmosphere after the 8 yr<sup>(55)</sup>.

Principle 3 refers to the adoption of management practices to improve animal health and welfare<sup>(8)</sup>. Management and treatment of parasite infections in livestock causes farmers to overuse anthelmintic (deworming) drugs, driving increased parasite resistance and putting animals at risk for untreatable infections<sup>(56)</sup>.

The following practices are recommended for proper parasite management: graze young animals on cleaner pastures; avoid overgrazing in order to prevent them from feeding close to the ground where parasite larvae reside; use rotational grazing; implement multi-species grazing; break parasite cycles by producing hay once a year; provide good nutrition to cattle, clean water, and a mixture of trace elements, and make a genetic selection of heads of cattle that are more resistant to internal parasites<sup>(57)</sup>.

Principle 4 values the health of the agroecosystem by strengthening its "immune system" through the enhancement of functional biodiversity and the creation of appropriate habitats<sup>(8)</sup>.

An interesting practice to preserve the health of agroecosystems is the production of quality fodder, which improves the digestibility of cattle and reduces GHG emissions<sup>(50)</sup>. High digestibility silage-based diets have been shown to reduce GHG emissions by 17 % compared to lower digestibility diets. Pasture and legume systems contribute as carbon sinks<sup>(58)</sup>.

In the same situation, reducing the use of machinery, lowering the grazing intensity, good manuring practices, a strict plan to reduce air pollutants, and maintaining a permanent ground cover to reduce wind erosion, all can reduce the risk of wind erosion<sup>(48)</sup>.

On the other hand, avoiding contamination of water sources and their proper management in the cleaning of corrals, planting crops that do not require irrigation, organic soil management, the use of drainage furrows, the non-use of herbicides, and the use of mobile water troughs for livestock are practices referred to principles 5 and 7 (Table 2)<sup>(48)</sup>.

### **Economic dimension**

In this dimension, it is necessary to maintain the competitiveness of production units in order to face the economic crisis<sup>(48)</sup>.

The current economic crisis leads to the application of agroecological principles in cattle production. The principles in Table 3 are achieved through the following practices: improving grazing systems; producing grass and hay forages; improving manure use; maintaining soil fertility; switching to breeds with lower production but greater local adaptability; returning to dual-purpose cattle in tropical areas; keeping herd size proportional to the surface area of the production unit; reducing inputs and economic investment; promoting healthy products in local markets, and generating economic savings<sup>(5,48)</sup>.

Small farmers can become self-sufficient, make a difference to their bottom line, and achieve a sustainable future by applying the principles in Table 3<sup>(31)</sup>.

The first agroecological principle of the economic dimension seeks to reduce or eliminate the input and dependence on synthetic or manufactured inputs, and to use materials of natural origin<sup>(5)</sup>.

**Table 3:** Agroecological principles of the economic dimension

Principles	Reference
1. To reduce or eliminate the input and dependence on synthetic or manufactured inputs and utilize naturally occurring materials for production.	(5,7,44,45)
2. To diversify the producers' agricultural economic income in order to build a transparent network between producers and consumers, and to provide decent livelihoods by promoting markets for selling their products at fair prices, as well as sound local economies and jobs, where the profits are used to achieve a social objective and maximize the return on invested capital.	(7,41,43,44)

A diversified production unit may be able to overcome the economic crisis mainly by reducing inputs such as the use of herbicides and chemical fertilizers, avoiding soil tillage, and eliminating the use of antibiotics<sup>(5)</sup>. It should be noted that avoiding these substances and activities enhances soil fertility, prevents disease outbreaks, reduces market price fluctuations, strengthens the variety of marketable products, and contributes to the development of a profitable livestock system<sup>(48)</sup>.

On the other hand, local breeds of animals allow reducing the dependence on inputs and increasing productivity, as they are breeds that have a considerable longevity and are resistant because they are well adapted to temperature changes in tropical areas (i.e., choose genotypes that resist heat stress). With these characteristics, it is possible to avoid industrialized production, dependence on concentrates and supplements, and reduce veterinary visits<sup>(12)</sup>. It is also reported that local plants (grasses, cereals, trees, etc.) are more resilient to climate disturbances and use fewer inputs. Furthermore, the use of local plant species reduces dependence on external varieties and promotes the agrobiodiversity of the system. Studies carried out in tropical silvopastoral systems with local forage plants have shown that the use of legumes reduces the use of synthetic fertilizers, representing an economic saving for producers<sup>(50,55)</sup>.

Another practice is the use of equines (horses, mules, donkeys) and bovines (cattle, oxen, buffaloes) for efficient weed control, helping to save fuel, herbicides, and labor. In addition, these animals provide organic fertilization with their manure and are used for loading, transportation, and traction activities to pull carts or plows<sup>(5)</sup>. The use of these animals lightens the workload and contributes to the economy of the production unit<sup>(59)</sup>. Energy provided by animals represents an accessible resource for small producers. This energy can be considered renewable, as it is fed with by-products and crop residues, and can be replaced when necessary<sup>(60)</sup>.

In this principle, it is important to enhance producers' capacity for fodder production and cost reduction and to develop new approaches that may help reduce waste and pollution<sup>(61)</sup>. It should be noted that grazing forage replaces the use of preserved fodder, expensive or imported grains, lowering input costs<sup>(57)</sup>.

Rotational grazing is a common practice to reduce dependence on concentrates and supplements for cattle feeding. In addition, it ensures the intake of high-quality forage<sup>(57)</sup>.

Another common grazing practice is strip cropping, where annual crops are used and the animals move towards these crops, using allocated strips according to the amount of feed apportioned for a short period of time, thereby optimizing feed efficiency<sup>(57)</sup>.

Finally, the literature suggests reducing expenditures on energy resources with the implementation of renewable energies (biogas, wind energy, solar energy, biomass, and biofuels)<sup>(62)</sup>. These energies also represent assets that can be used or sold as fuel and building materials, or exchanged for other products<sup>(49)</sup>.

Principle 2, on the other hand, seeks to diversify economic income by selling their products at fair prices, generating strong local economies and jobs, through the construction of networks between producers and consumers, to provide decent livelihoods<sup>(5)</sup>.

There is great consumer interest in agro-organic milk and meat produced without the use of antibiotics or hormones. Therefore, it is important to develop collaborative alliances for the commercialization of the products and to promote the labor process in an artisanal manner<sup>(57,61)</sup>.

One practice that could diversify the economic income of families is to apply agro-tourism, nature conservation and education, with attractive options<sup>(62)</sup>. It is also necessary to provide economic incentives to encourage people to return to rural areas<sup>(62)</sup>. One way to do this is to improve the attractiveness of rural areas and to carry out other rural development activities that benefit livestock producers, directly or indirectly<sup>(63)</sup>.

In this principle, fair trade, social and solidarity economy cannot be reduced to simple standards and must be focused on fair trade of products<sup>(43)</sup>.

## Political dimension

Citizen-driven agroecological policies and practices under governance structures are important for food security and nutrition for all<sup>(64)</sup>. In order to strengthen these decisions, principles have been established for the political dimension, focusing on social organizations with agroecological innovations and technologies<sup>(37)</sup>.

Principle 1 (Table 4) seeks to strengthen institutional power among the members of an organization to make democratic decisions. Democratic governance speaks of the importance of an exchange of information among all social actors<sup>(43)</sup>.

**Table 4:** Agroecological principles of the political dimension

Principles	Reference
1. To strengthen institutional power among the members of an organization to make democratic decisions to improve, recognize and support family farmers as sustainable managers of land, natural and genetic resources governance.	(43,44)
2. To promote social organization and participation in decision-making with producers and consumers in order to support local management, prioritize needs and interests, propose a control of biodiversity and territories, change power relationships, and offer new governance structures with supportive public policies, encouraging social organization for flexible collective management from the local to the global level (organization of farmers, consumers, researchers, etc.).	(41,44)

On the other hand, despite recent advances in public policies to promote food security in the world, according to the Regional Overview of Food and Nutrition Security 2021, there are still many cases of malnutrition in Latin America and the Caribbean<sup>(65)</sup>. In just one year and within the context of the Covid-19 pandemic, the number of people living with hunger increased by 13.80 million, reaching a total of 59.70 million people, the highest number in the last 20 yr<sup>(65)</sup>. It is important for social movements and civil society to work with governments to address malnutrition, as well as influence political priorities<sup>(64)</sup>. Given that animal foods are relatively expensive, policies should be implemented to make them more affordable or available to the poor<sup>(37,49)</sup>.

Principle 2 encourages the organization and participation of key stakeholders to achieve collective management from the local to the global level. The main community actions to achieve this are inclusive, accountable, and place-based processes; where risks, resources

and responsibilities are shared<sup>(66)</sup>. Organized groups are an example of good governance, where multiple stakeholders participate and are part of the decision-making process<sup>(67)</sup>.

In the political dimension, there are few recognized agroecological practices. France established an agroecological policy in December 2012. However, the recent Common Agricultural Policy (CAP) of the European Union defined in 2014 to 2020, provides for two pillars based on agroecological practices: direct payments and rural development<sup>(7,41)</sup>.

## **Relevant initiatives to transform livestock systems**

The multiple crises in the environmental, economic, food, energy, health, and migratory dimensions call for a transition to more sustainable processes and practices in livestock systems<sup>(68)</sup>. Redesign, reactivation of traditional systems, dissemination of successful agroecological initiatives at the local level<sup>(69)</sup>, knowledge sharing, practice, and collaboration among the main actors are key elements to promoting it<sup>(42)</sup>.

In this conversion, evolution or transformation towards sustainable systems, the reference<sup>(45)</sup> establishes a parameter for the degree of sustainability through the following levels: 1) Increasing the efficiency of processes and practices, reducing consumption and use of harmful inputs; 2) Replacing industrialized practices and inputs with sustainable alternatives; 3) Redesigning the production system to operate on the basis of a new set of ecological relationships and processes, and 4) Changing the ethics and values, and the re-establishment of a more direct connection between those who grow the food and those who consume it, with the aim of promoting a culture of sustainability that takes into account the interactions between all the components of the system<sup>(70)</sup>.

In order to understand the degree of agroecological transition, recent initiatives were identified based on the quality of information, agroecological principles, and elements they contain for their conversion to sustainable systems.

## **Agroecological transition of three production units in Mexico**

The following initiatives correspond to agroecological interventions in beef cattle production units in the Mexican tropic region.

First, "Las Cañadas" located in Huatusco, Veracruz, a cooperative made up of 22 members who produce corn, beans, tubers, vegetables, fruits, mushrooms, eggs, milk, cheese, and a little meat, in order to provide good food for their families. Its agroecological transition began in 1995, when it was decided to sell the *Bos taurus* (Simmental and Swiss-Cebu) breeds and to acquire registered Jersey cattle. In addition, the ecological restoration of the production unit was divided into two types: 1) Active restoration: planting 60 ha with 50,000 Mexican endemic trees of the following species: oaks (*Quercus*), walnut trees (*Juglans pyriformis*), liquid amber tree (*Liquidambar styraciflua*), chinaberry tree (*Melia azedarach*), moringa (*Moringa oleífera*), golden shower (*Cassia fistula*), and beech (*Platanus mexicana*); and 2) Passive restoration: leaving the rest of the area (160 ha) without grazing or human intervention, so that nature could take its course. In 2004, forage banks were planted for cutting and hauling in order to have a more intensive use of land and more animals per hectare compared to the practice of grazing. However, cutting and hauling increased the cost of labor and, therefore, these practices were discontinued. In 2006, the cooperative was integrated, where the highest authority is the members' assembly, and decisions are made by the majority of votes obtained (one member, one vote). Initially, the dairy products were marketed in Mexico City. However, in 2007, the cooperative stopped marketing its products and decided to redesign the livestock area. In 2010, the Voisin Rational Grazing (VRG) system was implemented. This system does not use agrochemicals, hormones, antibiotics, or chemically synthesized dewormers, only alternative methods such as homeopathy are used for the health of the animals. The cooperative is legally constituted and generates approximately 28 permanent jobs. In addition, it produces natural resources, applies technologies that allow less consumption of these natural resources, and produces 80% of the food for all members, besides being the main learning center on agroecology and permaculture in Mexico<sup>(71)</sup>.

Secondly, among the successful experiences of transition to sustainable livestock farming in Mexico is the production unit "Ganadería la Luna", located in the town of La Concepción, Jilotepec, Veracruz. Prior to cattle raising, this production unit was dedicated to growing sugar cane and coffee trees. The land was degraded and compacted. Following soil health monitoring by researchers from the Institute of Ecology (INECOL), a low richness of species, particularly of dung beetles (up to 50 % less than neighboring production units), was identified. In 2014, the use of agrochemicals, herbicides, and ivermectins was discontinued<sup>(72)</sup>.

Currently, this unit produces Brown Swiss cattle of the Brown Swiss breed. Different agroecological principles and practices such as VRG are applied. In addition, the wisdom and input of all those who work in the unit has been considered for decision making. One of the main results observed after the agroecological interventions is that the pastures changed from monocultures to mixed grasslands with native leguminous species that appear spontaneously, such as jumbay (*Leucaena leucocephala*), ice-cream bean (*Inga edulis*), and feather acacia (*Vachelia pennatula*)<sup>(72)</sup>.

On the other hand, biological corridors were created in the pastures and riparian zones (springs and streams); around the streams, a fence was placed at a distance of 4 to 5 m to prevent the passage of cattle, using live posts such as gumbo-limbo (*Bursera* sp.), izote (*Yucca* sp.), and hog plum (*Spondias mombin*). In 2016, these corridors obtained the Private Conservation Area (PCA) certificate granted by the Ministry of Environment, and by 2018, this unit evolved to be more biodiverse, highlighting strata of vegetation and timber trees<sup>(72)</sup>.

Finally, the third case corresponds to the "Loma Bonita" production unit, located in Ozuluama, Veracruz. This unit produces dual-purpose cattle of the Swiss, Zebu, and Holstein cross breeds. In 1986, this production unit applied methodologies promoted by agricultural technicians and professionals, used machinery to prepare the soil, and applied agrochemicals—practices that deteriorated natural resources. In 1994, Loma Bonita joined the *GGAVATT* "Aguada Primera", which was later incorporated as a company. In 2008, the issues in the production unit, such as deforestation, loss of biodiversity, soil erosion, low profitability due to dependence on external inputs, and adaptability of livestock due to breeds that are not suitable for the area led to the decision to change the production method. Training was received, and subsequently, a kilo of red Californian earthworm (*Eisenia fetida*) was acquired in order to obtain solid and liquid humus to improve the structure and nutrients of the soil. In 2009, the interest in creating a vegetable garden was born, and the course "The organic family vegetable garden" was taken. In 2010, agroecological interventions were carried out in the unit's system. The main interventions include the silvopastoral system with *Leucaena leucocephala*, the VRG system, zero soil tillage, and the reduction of agrochemicals, hormones, antibiotics, and animal feed. An area of approximately 30 ha was reforested with trees and shrubs of interest to the unit. In 2016, the stocking rate per hectare was increased from 1 to 1.50 livestock units (LU). In 2017, a stocking rate of 1.70 was achieved, and a production of 1,442 L of milk and 92 kg per ha, based on pasture with a minimum supply of concentrate. In addition, among the environmental benefits is that the VRG system has allowed dung beetles and earthworms to reproduce notably, as they have a medium of innocuous organic matter as food. The agroecological transition process in this production unit, where drought periods are prolonged, has allowed the production of cattle and other products to be less affected. However, it remains a challenge to maintain stability during each drought period. This initiative seeks to ensure that livestock farming lasts over time, provides welfare and comfort for the animals, and is an inexhaustible source of sustenance for the families that depend on it, while seeking the best quality of life for people and offering products that are ecologically healthy<sup>(73)</sup>.

## **Agroecological transition of three agroforestry systems initiatives in Brazil**

The following three initiatives correspond to interventions in forestry systems.

First, the "Fazenda da Toca Orgânicos" initiative arose during the search for better economic profitability of orange monoculture production, under the Green Revolution model. This production unit is located between native forests, villages, and research plots of the Toca Institute, and is owned by the Diniz family. In the Fazenda initiative, large-scale agroforestry activities are carried out to regenerate the soil, cultivate in a healthy way, encourage commercialization, and promote greater sustainability and profitability. The Fazenda initiative seeks to replicate successful strategies on the cultivation of native species as a basis for promoting sustainable forest management and obtaining healthier food without abandoning financial efficiency, i.e., working with agroforestry systems under an agroecological vision for the large-scale production of fruits and eggs<sup>(74)</sup>.

On the other hand, the "Mário Lago Settlement" initiative arose in the region of Ribeirão Preto, by a rural landless movement, where the members of the Landless Rural Workers Movement (MST) were displaced from their land by agribusiness, using the most fertile land and natural resources, forcing them to migrate to the cities. After lengthy legal proceedings against the agribusiness owner, the land was expropriated for settlement by a federal agency, the National Institute of Colonization and Agrarian Reform (Instituto Nacional de Colonização e Reforma Agrária, INCRA). This agro-industrial context was turned into an opportunity by the MST. The sugarcane agroindustry deforested and used many chemical products that degraded the soil and the Guarani aquifer. These environmental concerns prompted a Sustainable Development Plan to restore the role of the land in recharging the aquifer, as detailed in a federal agreement with the settlement. Under another state contract, it was decided that 35 % of the settlement area should be protected as Legal Reserve in order to restore agroforestry in Permanent Conservation Areas and use at least 15 % of the area in Agroforestry Agroecological Agroforestry Systems. This contract prohibits the use of agrochemicals in order to mitigate the agro-industrial effects of previous owners. In order to strengthen the initiative, a training and professional education space was promoted, with the aim of developing knowledge to address various difficulties related to agro-inputs, water scarcity, financial lending, etc. In addition, the Mário Lago initiative has managed state support for school food, technical assistance for cultivation, prices, transportation, and social security through the Sustainable Development Plan, thereby building a horizontal organization, although agricultural production helps to meet the food needs of all members of the initiative. This initiative aims to "stimulate a direct relationship between the producer and the final consumer", and in order to achieve this they obtained organic certification

through the Organização de Controle Social (OCS), by obtaining an official authorization of the Participatory Guarantee System as an alternative to costly organic certifications. Between 2016 and 2017, they promoted weekly food boxes that generated economic income. The initiative has incorporated scientific knowledge and seeks to further disseminate agroecology, agroforestry systems, agroecology, and regenerative farming. Its pillars include: participatory planning, cultivation, monitoring, evaluation, and training. Given the high cost of drip irrigation technology, systems are being designed with native plants that adapt and provide higher productivity<sup>(74)</sup>.

Finally, the initiative "Fórum de Comunidades Tradicionais" (FCT) arose in response to threats from the construction projects of residences for tourism in this area. Such projects threaten traditional ways of life in the area. The initiative brought together three communities: Quilombolas (descendants of runaway slaves), Indians and Caiçaras (a name of indigenous origin for coastal dwellers, often engaged in agriculture or fishing). FCT seeks to maintain, protect and regenerate its territory, demanding socio-environmental justice and greater public visibility for its culture and way of life. The FCT promoted community forms of nature conservation, agroforestry, and political defense of its territory, and has also developed Agroforestry Systems within the coastal forest in order to link the way of life with environmental conservation. This initiative is inspired by agroforestry traditions and by the dialogue of new forms of knowledge. Their production is marketed collectively, for example, in schools, public fairs, and various regional markets. The three FCT communities have designed a community-based tourism, "a tourism based on community management and the valorization of local knowledge". Revenues are shared equally by all members of each work team. For these novel forms of production, the FCT has promoted a dialogue between traditional knowledge and the new knowledge of NGOs, universities, and scientists, especially through state support programs and the Oswaldo Cruz Foundation. In a coastal area, the FCT has adapted permaculture methods as a social technology for ecological production, predominantly its action-research approach for the improvement of its social benefits, expressing that "with a socio-environmental perspective, they are a social technology incubator that is implementing agroecological practices on a larger scale"<sup>(74)</sup>.

### **Agroecological transition of the production unit "Hereafter the farm" in Sweden**

The production unit "Hereafter the farm" is located in east-central Sweden, where it produces beef and crops for food, feed, and biofuels. Before the agroecological transition, this large-scale production unit fed 1,200 steers with purchased feed and silage crops under intensive use of chemical fertilizers and pesticides. In 2017, livestock in the production unit contributed

6.20 million kg of CO<sub>2</sub>e, which decreased to 1.90 million kg in 2020. The values presented here refer to the system's own indicators. In 2018, began its transition by eliminating the purchase of calves to have only cows that were fed on pasture and silage, produced on the same production unit through crop rotation and the use of organic fertilizers. As a benefit, biodiversity increased from 43 to 66 %, and animal welfare, from 59 to 84 %. In addition, product quality improved from 34 to 83 %. Pesticides were eliminated and organic certification was obtained, which increased the number of customers interested in the quality of the product. The use of nitrogen fertilizers was also reduced from 400 kg of total N/ha to 300 kg of total N/ha. This agroecological transition reduced the climate impact of cattle production by approximately 70 %. In 2019, this unit was selected to participate in the project "Understanding and Improving the Sustainability of Agro-ecological Farming Systems UNISECO), and with its participation achieved a greater transition from conventional and intensive meat production to a more sustainable one, and thus stopped depending on external inputs, strengthening the relationship between buyer and seller, and marketing its products in a more equitable way. Substantial changes occurred in 2020, by changing the type and quantity of inputs used. 350 heifers were raised on semi-natural pasture and silage, thus totally eliminating the need for external concentrates. By reducing their production, they lowered their annual invoicing and personnel payment costs. However, the production unit is still very market-oriented, doubling the number of buyers of its products. In addition, the "less but better meat" strategy is an important contribution to understanding the concept of sustainable meat. Its agroecological transition depends on local resources and more integrated management. However, agroecological practices implemented in crops are mostly "weak", while meat production is based on "strong" agroecological practices, in which it is important to rely only on available forage and to adjust stocking rates in relation to the availability of natural grasses<sup>(75)</sup>.

## Conclusions

Agroecological principles and practices have been identified as universal and are not governed by standards, so they can be applied and adapted to cattle farming in order to move towards sustainable production systems. In addition, it was found that the principles and practices can be adapted to different climatic zones (temperate, tropical or other) and reduce the impact that the civilization crisis has generated in cattle raising; thus, their application contributes to achieving milk and meat production with a low impact on the environment, guaranteeing food self-sufficiency and promoting the fair commercialization of quality dairy and meat products.

A key strategy for the transition of sustainable milk and meat production systems is to apply agroecological principles and practices according to the level, quantity, and quality of resources in each dimension (environmental, economic, socio-cultural, and political), so that the impact of agroecological interventions can be evaluated in a stepwise manner over various time periods and the level of sustainability can be determined.

In general terms, according to the analysis carried out in this document, the main conversion principles that should be applied in cattle production units seeking to initiate a transition to sustainability are organic soil management and crop diversification.

The impact that the civilizational crisis has had on milk and meat production has affected producers directly, so they have been willing to change their approach to production. This has been observed in the initiatives analyzed in this document, where the main objective of the producers is to maintain milk and meat production levels with the least possible inputs and with a low impact on the environment, also achieving the formation of working communities and the exchange of knowledge.

In the transition initiatives analyzed in this document, an important application of agroecological principles and practices was observed where the reduction of agrochemical and input use is one of the main practices applied. In addition, improved grazing systems and ecological restoration have been crucial. On the other hand, the redesign of their production units taking into account biological corridors and the selection of local plants and animals have been of vital importance. Finally, in all the initiatives there has been a link between producers and researchers, as well as an organization for product planning and commercialization. The latter has set them apart from other approaches that seek to transition to sustainability.

The proper application of agroecological practices depends to a large extent on the willingness, motivation, and empowerment of cattle producers. In this way, disseminating, expanding, and applying agroecology has proven to address the problems that have affected various food production units.

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### Conflict of interest

The authors declare that they have no conflict of interest.

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