ANIMAL AGRICULTURE AND CLIMATE CHANGE: A QUALITATIVE HOLISTIC NOTE

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ABSTRACT

We are living in an era of rapid planetary change, often referred to as the Anthropocene. Environmental problems are so grim that there is currently a warning to humanity, subscribed by circa 11,000 scientists, calling on political, non-governmental and business leaders to take action before life on Earth reaches a tipping point. Extinction rate appears as one of the gravest issues. There has been a shift from a world dominated by wild animals to one mainly composed of humans and their livestock. Severe implications of this deleterious shift including alterations in biogeochemical cycles- as carbon sequestration-which influences climatic stability, are at stake. Aiming at attending the growing demand for meat and other animal derived products, animal agriculture is at the core of this ecological catastrophe: land use change has been strongly related to the expansion of soybean plantations and pastures, which are associated with alarming rates of deforestation and episodes of wildfires that cause habitat and biodiversity loss and highly impact local and regional hydric balance. These hurdles impair the performance of innumerable environmental services that depend on the intertwined biotic and abiotic components of the web of life. Robust evidence shows that a shift to more plant-based diets could stabilize greenhouse gas levels for three decades and offset nearly 70% of CO2 emissions this century.

KEYWORDS: *Deforestation; Defaunation; Biogeochemical cycles; Sustainable diets; Climate stability.*

THE PROBLEM

We are currently living in an era of rapid planetary change, often referred to as the "Great Acceleration". Progress[1] has brought many benefits to human societies. Yet we now also understand that there are multiple connections between the overall rise in our health, wealth, food and security, the unequal distribution of these benefits and the declining state of the Earth's natural systems. Human-induced change is so great that many scientists believe we are entering a new geological epoch: the Anthropocene [1].

Indeed, humans have already pushed four planetary systems beyond the limit of their safe operating space. These systems are: Biogeochemical flows; Land system change; Climate change; and Biosphere integrity (extinction rate), which appears as one of the gravest [2]. Concerning biodiversity loss, Smith et al. point out that there has been a major shift from a world dominated by wild animals to one largely composed of humans and their livestock [3]. This study, which focuses on mammalian biomass, point to dire consequences of this deleterious shift, including alterations in biogeochemical cycling, and carbon sequestration, among others. In a holistic perspective, the consequences may be rather disastrous because of the degree of incertitude of unforeseen events that may arise from this biomass quality transformation.

Agriculture is the primary force behind the transgression of the boundaries for nitrogen, phosphorus, climate change, biosphere integrity, land-system change and freshwater use. Many of these issues are interlinked, aggravating the challenge: climate change, for instance, adds further stress to land systems, worsening existing risks as land degradation and biodiversity loss [4]. And when we contemplate that a quarter of the earth's terrestrial surface is used for ruminant grazing and a third of the global arable land is employed to grow feed for livestock [5], we realize how animal agriculture, in particular, is a colossal force in this process. As habitat degradation is the leading cause of biodiversity loss, it is not surprising that vertebrate populations have declined sharply: the global Living Planet Index (LPI) shows an average 68% decrease in population sizes of mammals, birds, amphibians, reptiles, and fish between 1970 and 2016[4].

Furthermore, only 4% of the terrestrial mammal biomass is composed by wildlife. An astonishing 96% is composed by humans and animals raised by humans, especially livestock [6]. This is of much concern because the cattle are not able to perform the same ecological functions as the megafauna/wild animals [3]. There is therefore a gigantic loss of the ecological role of this faunal diversity with respect to many natural cycles.

Carbon storage is widely acknowledged as one of the most valuable forest ecosystem services. Deforestation, logging, fragmentation, fire, and climate change have significant effects on tropical carbon stocks, and an expressive decrease in carbon storage may be due to defaunation of large seed dispersers. Many large tropical trees with crucial contributions to carbon stock rely on large vertebrates for seed dispersal and regeneration. However, many of these frugivores are threatened by hunting, illegal trade, and habitat loss. Using a large data set on tree species composition and abundance, seed, fruit, and carbon-related traits, and plant-animal interactions to estimate the loss of carbon storage capacity of tropical forests in defaunated scenarios, one research found that defaunation has the potential to significantly erode carbon storage even when only a small proportion of large-seeded trees are extirpated. The study, conducted in thirty one Atlantic Forest communities, demonstrated that defaunation poses a serious risk for the maintenance of tropical forest carbon storage [7].

The findings of the authors quoted above are not surprising. Biodiversity is declining at different rates, in different places, but in the tropical sub-regions of the Americas[2], there has been a 94% decline in the LPI, the largest fall observed in the world [4].

Another study conducted in southeastern Amazonia reinforces the importance of animals in the scenario here discussed: lowland tapirs (*Tapirus terrestris*) have the potential to support natural forest regeneration by dispersing a variety of seeds over long distances, offsetting human and natural disturbances such as fragmentation, fires, and extreme climatic events. These large-bodied frugivores travel and defecate more often in degraded forests, dispersing much more seeds in these areas than in undisturbed forests. By effectively dispersing seeds across disturbed forests, tapirs may contribute to natural forest regeneration—the cheapest and most feasible way to achieve large-scale restoration of tropical forests. Through the dispersal of large-seeded species that eventually become large trees, these animals also contribute indirectly to maintaining forest carbon stocks. These functions may be critical in helping tropical countries to achieve their goals to maintain and restore biodiversity and its ecosystem services, as well as the recovery of degraded forests [43].

According to Stokstad, half of all plant species depend on birds and mammals to carry their seeds to new habitats. The author fears a slow death concerning the Earth's forests and ecosystems because as animals are killed by hunters or forced away by logging, etc., the plants that depend on them to carry their seeds tend to disappear. Over time, trees and

[1]Progress is a polysemic word used to qualify many different sorts of both quantitative and qualitative advances. It should also be stressed that the quoted "progress" has taken place mostly in the West.

[2] The thirty-one Atlantic Forest communities studied by Bello et al. are a tropical sub-region of South America [7].

other plants may vanish. Stokstad claims that climate change is accelerating this process, and the consequences may be not just the loss of biodiversity, but the ability of ecosystems to store carbon and provide food and clean water [8].
As a consequence, reforestation programs[3] and policies aiming at reducing carbon emissions are of course welcome, but not enough to halt the current apocalyptical process because reforestation cannot provide the original biological status of an ecosystem, in terms of species richness/diversity and complexity. Reforestation is therefore only a first and necessary step or at most, a palliative.

In reality, causes and effects are intertwined. Such quali-quantitative changes make much sense in a systemic view – still rare in the dominant mechanistic science – and are in consonance with the 'Gaia Hypothesis' proposed in the 1960s by Sir James Ephraim Lovelock. Consistent with this scientific theory, strongly anchored in the biogeochemical functioning of the planet, life and the physical components of the Earth are inextricably interrelated forming a complex system capable of maintaining a certain global homeostasis, including climate stability. Interdependence, feedback, and emerging properties are keywords here.

Given the data and scenario quoted before, it is not difficult to realize how the growing demand for meat – and other animal derived products is at the center of this ecological calamity which affects many other aspects of our life. Nevertheless, is there a genuine effort to counterbalance these problems?

In Brazil, for instance, cattle slaughter grew 3.4% in 2018 and pig slaughter increased 2.4%, reaching a new record, getting as far as 44.20 million heads. Chicken slaughter, despite a fall of 2.5% in 2018, totaled 5,70 billion heads and egg production increased 8.6%, another new record in the historical series started in 1987.In 2018 the amount raised by beef cattle in Brazil hit the significant sum of R$597.22 billion. The figure represents an increase of 8.3% compared to R$551.41 billion registered in 2017. This number is the largest ever recorded in the last ten years. In 2018 there was a 6.9% increase in the number of slaughters, reaching 44.23 million heads. As a consequence, there was also a growth in the volume of beef produced, an increase of 12.8% over 2017. In terms of herd size, in 1972 there were 92.5 million heads in the country, and in 2018 this number rose to 214.69 million. Brazil has the largest cattle herd in the world and is the largest producer, exporter, and the second largest consumer of meat, just behind the US [9].Regarding beef, although throughout 2021 there has been a reduction of 7.8% of slaughters, compared to the previous year, the slaughter of chickens increased 2.8% and with reference to pigs, the accumulated for 2021 recorded a record slaughter of 52.97 million head, representing an increase of 7.3% (+3.61 million head) compared to 2020 [10].Anyway, cattle slaughter started to grow again in 2022 after two years of decline [11].

This huge demand for meat has catastrophic consequences. According to Salomão et al., around 44% of the annual deforestation in Amazon, between 2019 and 2020, took place on non-destined public lands (NDPL). This study also showed that between 1997 e 2020, 75% of the deforested areas became pastures and remained so after ten years of conversion. Besides, over a period of ten years, the area deforested in NDPL not only continued to be occupied by pastures, but the proportion of this land use has increased five percentage points compared to the periods 2006-2010 and 2016-2020.This means that there has been economic investment to maintain and convert new areas of forest for livestock in that period[4][12].

Pastures are the main land use in Brazil, with circa 154 million hectares. If areas planted with soybeans and corn (estimated in 72 million hectares; most of which for animal feed) are added, we have in Brazil an area bigger than the biome Cerrado destined to animal agriculture[5]. However, the area occupied by cattle is even greater if we also include the natural fields that cover 46.6 million hectares, and mosaic areas of agriculture and pasture that occur in a consortium way and cover 45 million hectares. From 1985 to 2020, at least 252 million hectares are or were pastures. Satellite images detected two distinct phases in the conversion process that transformed almost a third of the country into pastures in that period. In the case of the Amazon region, data show that the area occupied by livestock between 1985 and 2020 increased 38 million hectares – a rise of about 200%. This growth has made the Amazon the biome with the largest area of cultivated pastures, with 56.6 million hectares [13].

Still concerning the annihilation of forests (and other natural ecosystems), as plants are the dominant kingdom on planet Earth [6], it is not difficult to realize the huge impact of deforestation and wildfires[6] when it comes to climate change. In order to produce so much animal products there is a need for major changes in land use, especially through

[3] A recent study shows that reforestation of agricultural lands in Europe increases local and downwind summer rainfall, and that realistic levels of tree planting could mitigate future droughts expected with climate change [32].
[4]The authors also point out that this process is usually linked to uncertain land rights, violence, and corruption, and that it is therefore urgent to give a destination to these public forests as determined by the Public Forest Management Law of 2006 [12].
[5]New data show that the production of such commodities tends to rise [33].
[6]One study suggests that the majority of anomalously high fire occurrences in the Amazon since 2003 did not occur in anomalous drought conditions. The intensification of agricultural fires and deforestation aggravated the burning of Amazonian ecosystems in 2020 [34].

deforestation[7]. Wildfires and deforestation cause the degradation of soils (a biogeochemical component) among many other harmful effects that are the aftermath of the conversion of natural ecosystems into pastures or feed crops. The problems triggered by such actions are weaved one into another in a framework that involves habitat loss, biodiversity loss, and changes in water balance, to name a few. Such transformations feedback deleteriously: loss of biodiversity[8]– from the bottom to the top of the trophic chains–affects biogeochemical cycles (such as carbon, nitrogen, phosphorus, oxygen, etc.) and deforestation affects evapotranspiration[9] which, in turn, affects several other so-called 'environmental services'[10], including the provision of food for humans.[11]

To Stohr[12] forests account for 25 percent of the world's biomass, and the fine root systems of trees are responsible for 75 percent of forest biomass production. This organic matter is essential to soil health and acts as a food source for many different species. Forests also account for 70 percent of terrestrial biodiversity, and most of it is found belowground (50 percent of animal biodiversity is found belowground). These often-forgotten ecosystems, where bacteria, fungi and nematodes, among many others, thrive are more diverse than the aboveground, and these species are responsible for many ecosystems that plants, animals, and humans rely on, including water purification, soil health, and decomposition. Furthermore, the majority of a forest's carbon storage and sequestration, essential for mitigating climate change, happens belowground: regarding climate stability, both nutrient cycling and carbon storage take root in the soil. Nutrient cycling – including the nitrogen cycle and the carbon cycle – largely takes place belowground. Thus, considering that the aboveground and belowground ecosystems are inextricably linked, converting forests to agriculture can decrease plant diversity and impact nutrient cycling, which in turn affects the food web and biomass inputs into the ecosystem. The author emphasizes the need of effective decision making at the scientific, policy and global level to increase focus on belowground ecosystems and positively advance scientific research and available funding for ecological restoration of the complete forest environment [14].

This overall imbalance also affects non-terrestrial ecosystems impairing (through eutrophication, for instance) other sorts of Earth's microbial life, which perform critical ecological functions. In our oceans, for example, where 90 percent of life is microbial, phytoplankton play the same role as green plants on land, fueling animal life as a starting point in the food web. Many negative outcomes to marine life may arise if phytoplankton´s productivity is damaged [15].

Taking into account the whole picture through a systemic, holistic "lens" it is much possible that the main factors affecting the global climate might not be primarily related to direct GHG emissions but to those mentioned above, responsible for the annihilation of homeostatic and resilience mechanisms in a global scale: deforestation, conversion of natural ecosystems to pastures and commodity plantations; consequent quali-quantitative changes in biomass (decrease on one hand/increase on the other) and loss of biodiversity, which affects biogeochemical cycles, etc. One consequence of this unprecedented anthropogenic imbalance is a tendency to get more and more extreme climate conditions. Let's just contemplate the fact that a single tree in the Amazon rainforest can load up to 1,000 liters of water per day into the atmosphere [16]. As evapotranspiration mechanisms in forests and savannahs, for instance, differ greatly from those of pastures or soybean plantations, we can expect a disastrous impact concerning this quali-quantitative transformation. In fact, analyses of streamflow data in major South American tropical river basins, show that increasing water use in agricultural zones and deforestation have amplified climate change effects on streamflow extremes over the past four decades. More severe floods and droughts are related to more extreme rainfall and deforestation and occur in 29% of the study area, including southern Amazonia. This regionally accelerating water cycle may have adverse global impacts on carbon sequestration and food security [17].

In truth, even considering direct emissions as the most powerful contributor, animal agriculture is an enormous threat to climate stability, as greenhouse gas emissions from animal-based foods are twice those of plant-based foods [18].

Animal agriculture has innumerous other negative impacts. Crop-livestock production systems are the largest cause of alterations of the global biogeochemical cycles of nitrogen and phosphorus because the total amount of nitrogen and phosphorus in animal manure (generated by livestock production) exceeds their use as fertilizers. As a consequence, excretion of nitrogen and phosphorus by livestock can lead to various types of land degradation and the excessive use of

[7]Deforestation in Brazil is completely out of control. The country is losing trees at a rate of 18 per second [35]. The demand for meat is the main factor. See, for instance, Brice [36].
[8] The main drivers of biodiversity decline continue to be habitat loss due to agriculture and overexploitation [1].
[9] The humidity produced in the Amazon is essential for the distribution of rainfall in the south and southeast regions of Brazil. The so-called "Flying Rivers phenomenon" originates in the tropical areas of the Atlantic Ocean and is fed by the humidity that evaporates from the Amazon Rainforest, is subsequently distributed to the other regions of South America. It´s easy to understand how deforestation affects this process directly: a tree with a treetop of 20 meters in diameter, for example, *breathes* an average of 1,000 liters per day [37].
[10] The term 'environmental service' reflects the pragmatic lens through which western societies relate to nature, and perpetuates the anthropocentric idea that nature is a servant to humankind.
[11]See FAO for the role of biodiversity in supporting and regulating ecosystem 'services', which, in turn, affect our food systems [38].
[12]See also Box [39].

manure and fertilizers per hectare of land often leads to contamination of water resources through runoff and leaching. In sum, robust data show one appalling component of the nitrogen cycle – the excretion of nitrogen as urine and faeces– associated with bovine meat production. Besides, generally, this enrichment of the environment leads to less biodiversity [19][13].

Also, according to Huddell et al., fertilized temperate croplands export large amounts of reactive nitrogen (N), which degrades water and air quality and contributes to climate change. Fertilizer use is poised to increase in the tropics, but much less is known about the potential consequences of increased tropical nitrogen fertilizer application. The authors conducted a meta-analysis of tropical field studies of nitrate leaching, nitrous oxide emissions, nitric oxide emissions, and ammonia volatilization totaling more than 1,000 observations. One important finding of this study was that pasture agroecosystems had higher nitric oxide losses. Hence, tripling of fertilizer N inputs to tropical croplands would have substantial environmental implications and would lead to increases in nitrate leaching (+30%), nitrous oxide emissions (+30%), nitric oxide (+66%) emissions, and ammonia volatilization (+74%), bringing tropical agricultural nitrate, nitrous oxide, and ammonia losses in line with temperate losses, while raising nitric oxide losses above them [20][14].

THE SOLUTION

Our environmental problems are so grim that there is currently a warning to humanity, subscribed by circa 11,000 scientists, calling on political, non-governmental and business leaders to take action before life on Earth, as we know, reaches a tipping point. As stated by this report, eating mostly plant-based foods while reducing the global consumption of animal products, especially ruminant livestock, can improve human health and significantly lower GHG emissions (including methane in the "short-lived pollutants" step). Moreover, this would free up croplands for growing much-needed human plant food instead of livestock feed, while releasing some grazing land to support natural climate solutions [21].

With respect to the dominant Western diet, it is interesting to note that two reports released more than a decade ago proposed, although timidly, a shift towards plant-based foods. One of them, entitled Assessing the Environmental Impacts of Consumption and Production – Priority Products and Materials, highlighted the importance of adopting essentially vegan/vegetarian diets [22], while the Global Biodiversity Assessment3 recommended more moderate levels of meat consumption [23].

In consonance with everything addressed here, the title of a very comprehensive paper on this issue resumes all we need: 'Rapid global phaseout of animal agriculture has the potential to stabilize greenhouse gas levels for 30 years and offset 68 percent of CO_2 emissions this century' [24]. This analysis has provided a quantitative estimate of the potential climate impact of a hypothetical, radical global change in diet and agricultural systems. The authors have shown that the combined benefits of removing major global sources of CH_4 and N_2O and allowing biomass to recover on the vast areas of land currently used to raise and feed livestock, would be equivalent to a sustained reduction of 25 Gt/year of CO_2 emissions[15]. Thus, all promising solutions to the climate crisis require some form of large-scale dietary change, once that eliminating animal agriculture has the potential to reduce net emissions by the equivalent of around 1,350 Gt CO_2 this century [24]. Another study shows that in terms of carbon sequestration through ecosystem restoration, shifts in global food production to plant-based diets by 2050 could lead to sequestration to an equivalent to 99–163% of the CO_2 emissions budget, consistent with a 66% chance of limiting warming to 1.5 °C [25].

Local examples of natural climate solutions (NCS)[16]reinforce the path towards a new holistic paradigm. According to a study, NCS could counterbalance 6% of industrial CO_2 emissions in China throughout 2020–2030, by trapping carbon within ecosystems and reducing greenhouse gas emissions. Implementing 62% of these NCS would cost ≤US$50 per megagram of CO_2 equivalent. NCS can contribute substantially to climate mitigation if appropriate planning strategies are employed[17].

These are definitely the kind of problem-solving approach we need, rooted in knowledge and ethically grounded choices. Many local small initiatives throughout the world would certainly promote a global success in terms not only of

[13] Farmers apply nitrogen-based fertilizer not only to increase crop yields for foods that we eat, but also for feed to sustain livestock. Excess nitrogen produces pollutants, which contribute to climate change, degrade freshwater quality, and impair our ability to breathe [40].

[14]Huddell et al. found that the relationship between nitrogen inputs and losses differed little between temperate and tropical croplands, although total nitric oxide losses were higher in the tropics [20].

[15] The total land use for animal agriculture inferred from their analysis is 33.7 million km^2, which is almost identical to the 33.2 million km^2 estimated by from satellite imagery [24].

[16]For a concise definition of natural climate solutions, see for instance: https://www.nature.org/en-us/what-we-do/our-insights/perspectives/natural-climate-solutions/

[17] See more in: Effective land management strategies can help climate mitigation in China [41].

climate change solutions, but also in terms of social, aesthetical, and ethical conquests. “Small is beautiful”[18]. It has always been.

It´s time to take a firm step towards halting climate change as its unforeseen consequences may turn out to be more and more uncontrollable. Recent satellite measurements point to a significant drop in Earth’s reflectance over the past two decades. Warming ocean waters are at the core of this problem. This specific context shows up as a grim surprise because for decades many scientists had hoped that a warmer planet might lead to more clouds which would then help to moderate the global warming process. Instead, the opposite seems to be happening[19].

Reducing the human population size and literally “greening” diet habits would make a huge contribution to tackle this problem. The first possible solution to mitigate this disaster is of course a very complex and difficult task and may be deceiving in terms of results. On the other hand, addressing the second – developing better, greener diet habits – is a much more feasible course of action. This is because size matters, of course, but rethinking overconsumption seems to be the central point here.

Sadly, as Eisen & Brown argue, it is surprising that changes in food production and consumption are not at the forefront of proposed strategies for fighting climate change. Although all of the strategies presented as part of the recent Intergovernmental Panel on Climate Change (IPCC) report on steps needed to keep global warming below 1.5˚C acknowledge the need for significant negative emissions, none propose even a reduction in per capita livestock consumption below current levels [24].

In line and recalling the idea of preserving a safe operating space for all life on Earth, Hirth suggests that performing vegan food practices as much as possible is an undogmatic responsibility of ethical producers and consumers alike, regardless of their personal identities as vegans, vegetarians or ‘meat eaters’ (carnists) [26].

It is of course necessary to admit that many obstacles lie in the way of promoting a shift towards a more plant-based diet, like cultural, economic, social, psychological and political hindrances ones, to quote a few[27, 28].Still, there should be a massive effort to overcome these hurdles because it is the very future of our species and millions of others, which are at stake. Moreover, this holistic necessary approach would help bridge the gap between us and the other animal species which are not merely components of a global equilibrium, but sentient beings [29, 30, 31].

Last, a touch of humor. Garfield (yes, the cartoon cat!) claims that *Diet is a “die” with a “t”*![20] For all we know now this is literally the case of our dominant Western diet: besides being cruel to non-human animals, raised with the sole purpose of becoming food, this cultural archaic habit is harmful to humans and is ravaging our planet. Let´s reverse this course of action while we still have time.

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