International Journal of Agricultural Technology 2023 Vol. 19(2):517-540
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Transforming meat based to plant based diet is addressing food security and climate crisis in this millenium: A review

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Mendoza, T. C. (2023) Transforming meat based to plant based diet is addressing food security and climate crisis in this millenium: A review. International Journal of Agricultural Technology 19(2):517-540.

Abstract All leaders of the world are at least climate-change aware, if not literate. All nations' state leaders who participated in the recently concluded 77th United Nations General Assembly consider climate change as the most challenging concern of this century. It is the aim of this paper to present how 50% reduction in global green house gas emissions by 2030 and net zero emissions by 2050 can be achieved to avoid a 1.5 degree centigrade rise in global temperature and its twin effects of global food shortage and hunger. Transforming meat based to plant-centric diet by reducing meat intake is the way forward. Meat is a very "resource use intensive" food. It takes 75 times more energy to produce meat than corn, 4 to 5 times more water than rice, about 8 to 10 times more land for one person to be nourished. The 3.5 billion pastures and meadows that are used for grazing ruminants animals can be freed and 56 % of the 1.2 billion grains produced annually and fed to animals (that include the pets-dogs, cats)and 90% of all soybeans are fed to animals can be used directly as human food. This implies that we do not need to increase food production by 60% or more when the population in 2050 reach about 9.1 billion or more. Animals are the main cause of deforestation and deforestation is the main cause of biodiversity loss, soil erosion/land degradation, loss of watershed led to disrupted hydrologic cycle, diminishing the supply of fresh/clean water in rural areas which are not serviced by local water utilities. Protein-based meat production is very inefficient, resource-use wise. Meat production requires lots of land, water, nutrients and energy, thus high energy footprint and ecological footprint in general. About 350 million tons of meat is consumed yearly which require slaughtering 80 billion animals per year. The greenhouse gas emissions equivalent in consuming this much meat is 72 % of the 31, 5 billion tons of CO_2eq.emissions. Other researchers reported 80% of the carbon emitted per year. Our calculation showed that transforming meat based diet to plant based diet, the avoided emissions is 22.681 billion tons CO_2eq (72%). While beef consumed is only 59.1 million tons, the carbon emissions per ton of beef is 221.63 ton CO_2eq, hence the highest at 13.098 billion tons CO_2eq.(42%) of all meat. Shifting to meat based diet is not sufficient. Greening production via adoption of regenerative organic agriculture could sequester 40% of global CO_2eq (@ 31.5 billion tons) if done in 1.46 billion croplands and the avoided emissions of 1.054 billion tons CO_2eq from non-use of synthetic fertilizer and pesticides, the 2 agrochemical inputs in conventional chemical agriculture. The sum of the 2 values (CO_2eq sequestered and CO_2eq emissions) avoided is

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13.654 billion tons CO_2eq. (42%).Add the 2 equals 36.335 billion tons CO_2eq. Greening food production and consumption yielded an avoided or reduced emissions which is 15% higher than the Carbon emissions of 31.5 billion tons CO_2eq. in 2018. Acceptably, 100% Green Production and 100 % no meat is difficult to achieve. In our sensitivity analysis, 5 scenarios were considered. A 50% carbon emissions reduction by 2030 can be achieved by reducing meat consumption by 50% +50% green production (Scenario 5). Net zero emissions by 2050 can be achieved by 100% Green Production and 80% less meat (Scenario 4). The adoption of green consumption (50 % no meat) implies that huge tracts of lands for pasture or grazing are freed where trees and carbon sequestering vegetation are left. Even if only 50% of the global pasture lands will be freed from grazing (3.5Bha /2= 1.75 Bha), the potential carbon sequestered per year in the soil is already 10 to 15 billion tons of CO_2 eq. The carbon emission attributed to non use of fertilizer and pesticide to grow grains shall lead to 2.8 billion to 4.7 billion tons of carbon emission reduction after 10 years. Adding the 2 freeing 50% of the 3.5 billion pasture lands shall lead to 10-15 billion tons of carbon sequestered via photosynthesis plus the 2.8-4.7 billion tons CO_2eq. Avoided emissions summed up 12.8 to 19.7 billion tons CO_2eq. (10 to 15 +2.8- 4.7) or 40.64%-62.5% reduction. The 50% greening consumption and production (57.68 % reduction in the avoided Carbon emission) and adding 40.64%-62.5% totaled 98.32% - 120.18% carbon emission reduction. An early net zero emission is achieved 2030 and not 2050. A meat-based food is not a diet for all, as poor people are priced out when a global food shortage occurs. Greening consumption through plant-based diet can feed us all, an inclusive diet or diet for all that will not price out the poor. Thus, an accelerated shift to plant-based/planetary health diet that will not harm us and also Mother Earth is necessary. Climate change is diet change. Less and less meat is the way to progressive shift to organic agriculture. The human-triggered global catastrophic food crisis can be avoided and the 6th cataclysmic forecast prevented.

Keywords: Carbon sequestration, Climate crisis, Diet change, Greening production and consumption, Organic agriculture, Net zero emission

Introduction

Of all the major crises, capsulized into “Four Cs” (Conflict, Covid, Costs, and Climate) climate crisis is the one leading us to the verge of global catastrophic food crisis (Muller *et al.*, 2022). The high ***costs*** of production is due to how food is produced via oil-based manufactured fertilizers and agrochemicals, tripled when the oil price doubled. In turn, this was due to the ongoing ***conflict***: Russian invasion of Ukraine. The biggest rise in hunger is concentrated in countries themselves affected by continuing conflict, such as Afghanistan, Yemen, Syria, Eritrea, Somalia and the Democratic Republic of Congo. The ***covid*** 19 pandemic has subsided and relaxed the low-fuel consuming lockdown that limits peoples’ mobility to contain the virus. People are back to their oil-guzzler cars plus their cars fueled through grains that are processed into biofuel (bioethanol and biodiesel).

The climate change-propelled drought in India, China, Europe, and the USA, mega floods in Pakistan, and the continuing dryness in Africa, increase

the number of people who are poor and hungry. The global hunger level is already at a new high, with as many as 1.7 billion people facing hunger. Countries such as Lebanon, Sri Lanka, Egypt, Sudan and Tunisia are facing serious food shortages, which have led to social unrest and as many as 193 million people around the world experiencing acute food insecurity – a jump of 40 million in a year (Biden UN remarks). Rice – the staple food of more than half of the global population – the United Nations' Food and Agriculture Organization Food Price Index already shows international rice prices creeping up (Global food prices are soaring. Rice could be next 2022, the staple food of more than half of the people of the world.(https://www.cnbc.com/2022/06/13/rice-prices-are-rising-amid-rising-food-inflation-export-bans-.html)

Indeed, there is good news amid bad news. All nations' state leaders who participated in the recently concluded 77th United Nations General Assembly considered climate change as the most challenging concern of this century. It is safe to say that all of them are now climate-change aware, if not literate. Foremost, US President Joe Biden said:

"From the day I came to office, we've led with a bold climate agenda. We rejoined the Paris Agreement, convened major climate summits, helped deliver critical agreements on COP26. And we helped get two thirds of the world GDP on track to limit warming to 1.5 degrees Celsius.

"… The United States is opening an era of relentless diplomacy to address the challenges that matter most to people's lives: tackling the climate crisis… strengthening global health security; feeding the world…

"And now I've signed a historic piece of legislation... that includes the biggest, most important climate commitment we have ever made in the history of our country: $369 billion toward climate change… Our investments will also help reduce the cost of developing clean energy technologies worldwide… This is a global game changer – and none too soon. We don't have much time.

"We all know we're already living in a climate crisis."

Total climate finance averaged $632 billion per year in 2019/2020.However, the estimated needed investment per year was $4-5 trillion to meet global decarbonization goals. (https://www.weforum.org/agenda/2022/02/how-private-capital-can-be-leveraged-to-fight-climate-change/)

The United Nations' Intergovernmental Panel on Climate Change (IPCC) Chair Hoesung Lee said that greenhouse gas emissions (GHGe) should be declining by 2025 to avert a "catastrophic" temperature rise. Approved on April 4, 2022 by the 195-member governments of the IPCC, all sectors must at least halve emissions by 2030 or 7 years from now. Carbon dioxide emissions would need to reach net zero by 2050 (less than 30 years from now). And to

avoid the most dangerous and irreversible effects of climate change, global warming should be limited to 1.5 degrees Celsius (https://www.google.com/search?q=when+to+achievehttps://www.google.com/search?q=when+to+achieve+net+zero+emissions+to+avoid+climate+crisis&rlz).

There should be accelerated decarbonization to achieve net zero emissions (Fig. 1) to keep global warming below 2 ℃, and ideally below 1.5 ℃ under COP26-Paris Agreements. Commonly cited ways toward decarbonization include reduction in fossil-fuel use, widespread electrification, improved energy efficiency, and use of alternative fuels (such as hydrogen), renewable energies and "having the right policies, infrastructure and technology to enable changes to our lifestyles and behavior''. But this will result only to a 40-70% reduction in greenhouse gas emissions by 2050, not zero emission. (https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/).

Listed in the cited measures will not lead or achieve net zero emission. *Changes to our lifestyles and* behavior is a vague or general word and it must be clarified. There are 2 general measures in achieving Net zero emissions (as shown in Figure 1) and they are as follows: 1) To reduce GHGe through an accelerated shift to renewable energy or by reducing to non-use of fossil fuel or oil-based energy; and 2) by sequestering back CO_2 e by planting trees (reforestation, agroforestry, mangrove reforestation), stopping deforestation and adopting organic/regenerative agriculture.

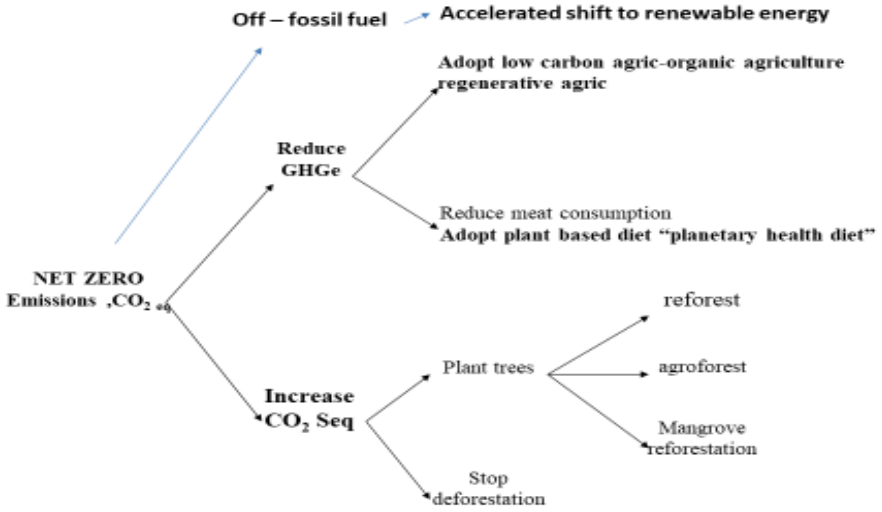


Fig.1. How to achieve net zero emissions of green house gases (GhGe)

This paper is an attempt to analyze and suggest how these GHGe goals could be achieved. As the food system is the major source of emissions (up to 57%, Grain International), it must be addressed by greening consumption or transforming our meat based diet to plant-based or 'planetary health diet." A synthesis of accessible information and analyzed through a food system approach led to the author's hypothesis *that a plant based diet complemented by regenerative organic agriculture are the twin pathways in accelerating decarbonization to save the world from the climate crisis-triggered global catastrophic food crisis.*

Brief background

There are three (3) major points where food becomes the major emitter of greenhouse gases: *1st*, the way food is produced; *2nd*, how food is made available (processing food, travelling long distances); *3rd*, how food is consumed (meat-based diet) and how it is wasted. But the driver on why food becomes the major emitter is population. So with the human induced green house gases emissions causing climate crisis. The world reached a population of 1 billion in 1758. Global population had breached 8 billion people in November 15, 2022. (https://www.onenews.ph/articles/global-population-to-breach-8-billion-on-nov-15).In nearly 264 years, the population grew 8 times. Population growth is tapering at an average increase of 82 million people/year. There will be 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100. There should be 60% increase in food supply by 2050? But 77% increase is needed in food-deficit developing countries where the majority of population increase will occur. Following same production systems, a 60% increase in food supply means 60% more land, water, nutrients, energy (fossil fuel oil). As stated earlier, the convergence of "Four Cs" (Conflict, Covid, Costs, and Climate) leads us to the verge of global catastrophic food crisis (Muller *et al.,* 2022). The climate change-propelled drought in India, China, Europe, mega floods in Pakistan, and the excessive dryness in California USA , the exact opposite situations in South Carolina, Florida ,USA, and the continuing dryness in Africa, increase the number of people who are poor and hungry. (https://www.cnbc.com/2022/06/13/rice-prices-are-rising-amid-rising-food-inflation-export-bans-.html) We are living in a world where one in 9 people is hungry; One in every 4 children under age 5 in developing countries is stunted; Over 2 billion people are suffering from micro-nutrient deficiency; 2.1 billion people are overweight, leading to diet-related non-communicable diseases and doubling the burden of malnutrition (Konuma, 2018). Population per se is not the culprit! It is rising incomes. Per capita food consumption per day had

increased from 2370 kcal/person/day in the 1970s to 2770 kcal/person/day in 2005/07(17% increase).This was found to be correlated with rising incomes. In general, the poor consume food at 1800-2,200 kcal/person/day, while the rich 3,700-4,000 kcal/person/day. Growing urbanization and diet globalization have evoked change in dietary habits, resulting in increased demands for meet, milk, eggs, fish, etc. Half of the world population lives in cities and sixty (60) percent of world population would live in urban centers by 2030 and nearly 70 percent by 2050. For Southeast Asia, nearly 63 percent of total population is expected to live in urban areas in 2050. This implies a rapid decline of agricultural labor force, changes in dietary habits, growth in the importance of urban and peri-urban agriculture to meet food needs, etc. (Konuma, 2018). Also, urbanization means more land-use conversion for housing, more water needs, food wastes to haul in dumpsites, and increases for food processing, storage, packaging, transport, hence, carbon emissions. Transporting food will become an energy/logistics nightmare! Moreover, food globalization contribute higher energy footprint as food is now travelling more than 10,000miles away to and from. In the case of rice, the staple food of more than half of the global population, when rice grains are transported more than 100 km, the energy bill per kg almost doubles (Oo *et al.,* 2021)

In Asia, the consumption of traditionally "Western" foods – wheat and wheat-based products, temperate-zone vegetables, and dairy products is growing (Conway 2012.) "One Billion Hungry: Can We Feed the World?" (https://www.jstor.org/stable/10.7591/j.cttq43v4). This increases the energy footprint of food when the need is to decrease it. A significant number of people in both the developed and developing countries are buying more processed and higher-value foods, while reducing their purchases of raw agricultural commodities.

How food is consumed and how it is wasted: More than half (about 56%) of all grains produced through heavily fertilized Haber-Bosch Nitrogen (consuming 1.8 li diesel oil equivalent/kg-N; (Clark, 2009)), hence, a high energy footprint, are fed to livestock. Some 60% of the wheat produced in Europe goes to animal feed, while 40% of the maize grown in the US is turned into fuel for cars. Thirty seven percent (37%) of all grains (200Mt corn eq.) is processed into biofuel. This translates to the food calories intake of 913 million people.

On a global level, 80% of the world's soybean crop is fed each year to animals while 23% of the world's palm oil is turned into diesel (https://grain.org/en/article/6862-lurching-from-food-crisis-to-food-crisis).
Additionally, we have an increasing number of pet lovers as shown in Box 1.

These pets (dogs, cats) consume about 180.4 million tons of corn eq. which is about 17% of the 1.02 billion tons of world corn consumed in 2016-17.

Box 1.World Pets

900 million dogs, 400 million cats; Food consumption of world pets = 180.4 million tons of corn eq. → 17% of 1.02 billion tons of world corn in 2016-17

Our food systems (production and consumption pattern) contribute about 44-57% (Grain, 2009) of the total GHG emissions (49% of these emissions come from livestock, 22% energy, 16% rice methane, 13% fertilization). More deforestation to expand pasture, forage and grains production for livestock will increase yields, thereby increase fertilizers and agrochemicals usage.

Called Green Revolution in the early 1960's, the production of food doubled and quadrupled in some areas. Industrial-chemicalized agriculture led proponents to claim that this food production revolution was a great "success" as it debunked the Malthusian prognosis that food will soon be in short supply. Population was only 1.0 billion when Malthus made the prognosis, and population reached about 8 billion by the end of 2022. But this food production revolution entailed a lot of burning fossil fuels, emitting lot of CO2eq. It cheapened the food due to food surplus, and because they are artificially cheap, it led to lots of food wastage (30%).Food prices are not inflation adjusted. Also, in accounting their total cost, the ecological costs, now valued as social costs of carbon are not included (Carolan, 2018 ; Mendoza, 2021). Americans spent $1.1 trillion on food in 2019.The true cost was at least three times higher if biodiversity loss, diet-related disease, and pollution, among other factors are included (https://stonepierpress.org/goodfoodnews/the-true-cost-of-cheap-food).

Moreover, industrializing food systems led to so much processed foods, stored, packaged, and transported to long distances, leading to huge energy footprints (food-miles effect). Fifteen (15) cal of energy is used to put foods on the table (10 cal to produce food and 5 cal more to process, store and distribute(https://www.google.com/search?q=how+much+calorie+is+used++per+calory+of++processed+foods). Massive production of grains using oil-manufactured production inputs (synthetic fertilizers and pesticides) allowed large production of livestock (poultry-broilers/eggs, hogs, even ruminants – beef cattle/dairy are now grain-fed.

The Ways Forward: Climate Change = Diet Change

Against that backdrop, there is urgent need to shift to low-carbon emitting food systems. There is an urgent need to transform our meat based diet to plant based or planetary health diet.

Transforming meat-based diet to plant-based diet is necessary

The global population is predicted to surge to 9.1 billion people or more by 2050. As stated earlier, it is not population per se which is the driver in triggering climate induced food shortage leading to the rebirth of Malthusian prognosis of population triggered food shortage 264 years ago. *It's the diets rich in meat and dairy* .The reasons are follows :

Aside from the inefficient conversion where, as a rule of thumb, 1.0 kg protein from animals requires 6.0 to 8.0 kg plant protein. Carbon emissions from meat are enormous, i.e., 1 kg of beef/mutton → 221.63 kg CO2e; 1 kg of pork → 36.3 kg, 1 kg of chicken → 31.75 kg CO2e, 1 kg eggs → 24.37 (Clark and Tilman, 2017).

Box 2. 80 billion animals slaughtered in a year (2019)

324,518,029 (890,000 cattle per day)
72 billion chickens (197 million per day)
3.3 billion ducks (9 million a day).
700 million geese and guinea (2 million per day)
630 million turkeys per year (1.726 per day) (US: 46 million killed and eaten in just one day –Thanksgiving)
500 million goats (1.3 million goats
602 million sheep (1.5 million sheep
1.3 billion pigs (3.5 million pigs)
630 million rabbits (1.7 million rabbits
80 billion animals slaughtered in a year (2019)
An average animal-eating U.S. citizen would consume 7,000 animals during his/her lifetime. (11 cows, 27 pigs, 2,400 chickens, 80 turkeys, 30 sheep and 4,500 fish; about 50 billion animals slaughtered)

* https://sentientmedia.org/how-many-animals-are-killed-for-food-every-day/

How much meat is consumed by meat lovers? About 350 million tons of meat is consumed in a year, which translates to about 52 kg per capita (Box

2). To make this huge amount of meat available, about 80 billion heads of cattle, sheep/goats, chickens, ducks/geese, turkeys, and rabbits are slaughtered in a year. An estimated 50 billion chickens are slaughtered for food every year – excluding male chicks and unproductive hens killed in egg production; 1.5 billion pigs are killed for pork, bacon, ham and sausages – a 3-times increase in the last 50 years; 0.5 billion sheep are taken to the abattoir every year and goats slaughtered are greater in number than cows eaten (the figure for cattle excludes the dairy industry). (How many animals we eat each year Feb 8, 2019 https://sentientmedia.org/how-many-animals-are-killed-for-food-every-day/).

The meat diet explains the massive expansion or conversion of large forests ecosystems into agroecosystems (Campari, 2018). Compounded by population and affluence which means more meat and animal products consumption (milk and milk ice cream, chocolates, candies).

Indirectly, animals are the major causes of deforestation, biodiversity decline, greenhouse gas emissions and the health crisis.

Animals are the major users of resources (land, water, nutrients, energy); 70% of all agricultural lands are devoted to pasture, forage and grain production to feed the animals. More than half (56%) of all grains is fed to animals. These grains are produced, processed, stored, distributed and fed to animals using oil-based inputs. The UN-FAO warns that using cereals as animal feed could threaten food security by reducing the grains available for human consumption. Increasing affluence is directly related to increased meat and dairy products consumption.

By 2030, it is projected that there shall be 60% middle class (4.75 billion people) and ¾ of global population (7 billion people) by 2050. Food demand shall increase by more than 60 percent, and animal-based foods by nearly 70 percent. There is no way to feed 10.0 billion people on a meat-based diet without harming Mother Earth and the environment. products (https://skepticalscience.com/animal-agriculture-meat-global-warming.htm).

Animals outnumber humans. There are 19 billion chickens, 1.5 billion cows, 1 billion sheep and 1 billion pigs living. At any one time, they are three times higher than the number of people. The production of meat has doubled in the 30 years from 1988 to 2018 and increased four-fold since the mid-1960s. At 350 million tons/year (2018), by 2050, global meat consumption is projected to reach between 460 million and a staggering 570 million tons. 570 million tons would mean a consumption of meat twice as high as in 2008. Meat is a very”resource use inefficient" food. Meat has a much higher “energy footprint” than any other food. It takes 75 times more energy to produce meat than corn. The top meat-eating countries are (kilos per person per year): The US: 124 kg, Australia: 122 kg, Argentina: 109 kg; New Zealand: 101 kg, Spain: 100 kg

(Philippines 29 kg; African countries less than 20). If everyone shared the meat-heavy diet of the average American or Australian, the world could feed only 2.5 B people (https://www.theworldcounts.com/challenges/consumption/foods-and-beverages/world-consumption-of-meat).

Because meat production is so demanding in terms of resources, it also affects biodiversity and contributes to the extinction of species, where 28.5% of all species are now in critical risks of extinction. WWF finds that 60% of global biodiversity loss is caused by meat-based diets. As a source of protein, meat uses a lot of fossil fuel energy. It takes an estimated 2-3 calories of fossil fuel to produce 1 calorie of protein from soybeans, corn, or wheat while beef takes 54 calories of fuel to produce 1 calorie of protein. Over 8 liters of gasoline are required to produce one kilo of grain-fed beef. Meat is a very “inefficient" food source. One hectare of rice or potato cropland can feed between 19 and 22 people in one year; one hectare for beef or lamb can feed only 1 or 2 people. At the same time, the world’s cropland area is shrinking. By 2050, we may have less than 0.1 hectare per person on the planet. Meat consumption is the main cause of the looming global food crisis. Almost HALF of the world’s harvest is fed to animals; 90 percent of the ever-increasing soybean harvest goes to animal feed. (https://www.theworldcounts.com/challenges/consumption/foods-and-beverages/world-consumption-of-meat).

In summary: Animals are the main indirect cause of deforestation for pasture, and feed grains production to feed them. Deforestation is the main cause of biodiversity loss, soil erosion/land degradation, loss of watershed leading to disrupted hydrologic cycle, diminishing the supply of fresh/clean water in rural areas which are not serviced by local water utilities. The main source of carbon emissions is decomposition of soil organic matter (underground biomass) and litterfall/left-over trees and branches after logging (aboveground biomass). Protein-based meat production is very inefficient, resource-use wise. Meat production requires lots of land, water, nutrients and energy, thus high energy footprint and ecological footprint in general.

On Land Resources: Of the total 13.157 B ha global land area ha, globally agricultural land area is 5 B ha (38% of global land) (Winkler, 2021). Global cropland is 1.65 B ha (1/3 of agricultural land area); 3.35 B ha or 2/3 of agricultural land areas are meadows and pastures for grazing livestock (https://www.fao.org/food-agriculture-statistics/en/). If only ½ of globally agricultural land area of the 3.35 B ha meadows and pastures for grazing livestock will be vacated and devoted to tree-planting to sequester back the CO_2 via photosynthesis, this will reduce by ½ the ruminants and thereby reduce

considerably the gases emitted: methane (28 times higher GWP than CO_2) and nitrous oxide (298 times GWP relative to CO_2).

On Water: So much water is pumped (using fossil fuel oil) to irrigate grains and forage for animal feeds. Adopting a ”demitarian diet" – cutting meat and dairy consumption in half – would lead to 40% cut in Europeans' intake of saturated fats and 25-40% greenhouse gas emissions from agriculture.

Rapid global phase out of animal agriculture can stabilize greenhouse gas levels for 30 years and offset 68 percent of CO_2 emissions this century that could avoid disastrous climate crisis.

Previous estimates of animal contribution to GHG are under-computed as 80% of all GHGe is contributed (directly & indirectly) by animals. My estimate is 72% (Table 1). GW/Climate Change-induced weather events such as flooding, sea level rise, food insecurity and other disasters have significant financial impacts on economies big and small, both in costs to repair damages and build back destroyed infrastructure and properties, medication & healthcare costs, and increased food prices. (https://www.health.harvard.edu/staying-healthy/becoming-a-vegetarian).

Livestock contributes about 40% of agricultural gross domestic product (GDP) and provides livelihoods and incomes for at least 1.3 billion people globally and phase out of meat animals shall have enormous negative economic impacts. But the meat industry is one of the costliest of all food production ways that impact the environment, healthcare and our individual wallets *(https://www.gobankingrates.com/saving-money/food/economic-environmental-costs-eating-meat/)*. If people in the U.S. continued to eat meat at the same levels of consumption rather than shift to more moderate or plant-based diets, it would cost the U.S. between $197 billion and $289 billion each year, and the global economy as much as $1.6 trillion by 2050. A shift away from meat could save the U.S. $180 billion if people ate meat per recommended dietary guidelines and up to $250 billion if people stopped eating meat altogether.

Why shift to Plant –centric *Planetary Health Diet*?

“Planetary Health Diet” is a global diet that meets humanity’s nutritional needs while protecting the planetary health. Planetary health is a new systems paradigm that integrates the health of the human civilization and of the natural systems on which it depends. This new discipline emerged in recognition of the Anthropocene – the proposed geological epoch which emphasizes the massive influence of human activities in shaping the dramatic changes afflicting the Earth’s geology and its ecosystems. One of the major human systems that are

driving these transformations is the food system. Food is essential for sustaining the health of human populations, but its production and distribution are exerting tremendous pressures on the Earth's vital processes (Guinto, 2021). Planetary Health Diet is a plant-centric diet, with a higher volume and diversity of pulses, nuts, wholegrains, tubers, vegetables fruits and less animal meat (1 meat based diet in a week)(*https://www.transformingfoodsystems.com/about.html.) The planetary health diet was introduced by The Rockefeller Foundation–Lancet Commission in 2015. It calls for transforming food systems which requires a significant redistribution of the primary factors of production within a period of 10 years. This includes significant the structure of landholdings, technologies and their use, capabilities of women and men, and the distribution and dynamics of the population and labor force. Effectively designed and implemented, such changes can generate multiple benefits, translating into transformed and thriving rural livelihoods and communities.* (*https://www.transformingfoodsystems.com/about.html)*

As stated earlier, the meat-diet is the main cause of land conversion from natural ecosystems to agriculture, the largest single cause of greenhouse gas emissions, linked to loss of biomass and carbon in biomass above- and belowground. Land conversion to agriculture is the major driver of biodiversity loss and land degradation. By limiting meat production (via people eating less meat), all the downstream impacts of carbon emissions can be saved, thus saving money and lives. Plant-based eating is recognized as a way to reduce the risk for many chronic illnesses. According to the American Dietetic Association, appropriately planned vegetarian diets, including total vegetarian or vegan diets, are healthful, nutritionally adequate, and may provide health benefits in the prevention and treatment of certain diseases. ("Becoming A Vegetarian,".2020. https://www.health.harvard.edu/staying-healthy/becoming-a-vegetarian)

If the world adopted a plant-based *Planetary Health Diet*, we would reduce global agricultural land use from 4 to 1 billion hectares; a global land use reduction for agriculture by 75% via reduction in land used for grazing and a smaller need for lands to grow crops for feeds. (Ritchie, 2021. https://ourworldindata.org/land-use-diets)

Global human population shifting to plant-based or *Planetary Health Diet* will reduce considerably the emissions via lesser use of energy-based inputs (fertilizers, pesticides) on grains produced to feed the animals (Guinto, 2021; Geels *et al.,* 2015), lesser lands needed to produce food, freeing these areas to grow trees, herbs, and converted to agroforestry/tree-based agriculture that will continuously photosynthesize to sequester back carbon in the air.

Shifting meat based to plant centric diet or planetary health diet is not enough to reduce carbon emission at 50% by 2030 and net zero emission by 2050.There is a need to transform our food production systems to less carbon emitting and make it carbon sequestering

Transforming industrial chemical agriculture to green agricultural production

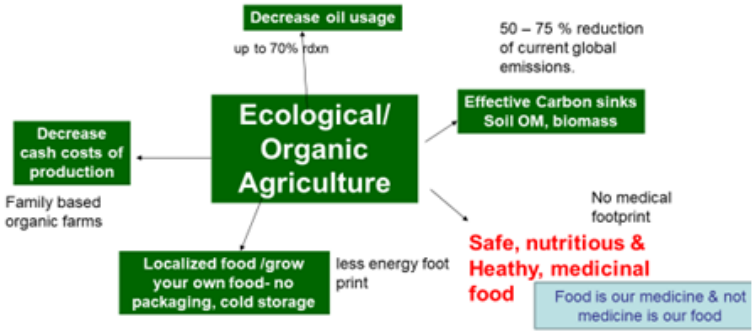
During the early decades of industrial chemical agriculture, it made food cheaper by 50%, reduced the number of hungry people from 35% to 17%; the abundant food supported baby boomers from the pre-war era of 1 billion to 7.9 billion now; debunked Malthusian prognosis since there was food surplus although population increased 8 times. (The Malthusian prognosis was made pre-climate change.)

But food systems based on Industrial Chemical Agriculture account for 57% of GHGe, causing global warming. If global temperatures reach 2 deg.C, this will decrease food by 10 to 30%, when we should be increasing food supply by 50 to 60%, a net shortage of 60 to 90%?

The annual economic costs of Industrial Agriculture has been calculated at $6.03 trillion. Accounting the real and total costs (Carolan, 2018) to include biodiversity loss, pollution costs, and health costs will multiply this costs 3 times (https://stonepierpress.org/goodfoodnews/the-true-cost-of-cheap-food). The amount needed for Climate change mitigation and adaptation is calculated to cost $4-5 trillion . The huge emitters, the developed countries led by the United States, only committed $394 billion. An eye-for-eye or tit-for-tat measures will not work.

As Einstein once said, *'Insanity is doing the same thing over and over again and expecting different results.'*

Greening production or shifting to low carbon-emitting food production systems (organic or regenerative agriculture, biodynamic farming, permaculture, ecological agriculture and more recently, agroecology-based agriculture) is the way to go. As described in the figure below.



The energy use and energy footprint of non-chemical/organic agricultural production systems are much lower than the conventional/chemical-based production systems (Gundogmus and Bayramoglu, 2006; Alfodi *et al.*, 1995; Edwards, 1987; N. Lampkin and S. Padel, 1994; Ozkan *et al.*, 2003; Pathak and Binning, 1985). In the study of Oo *et al.* (2021), organically grown rice uses 70% less energy (1.164 MJ/kg) relative to conventionally grown rice (3.83 MJ/kg).

Problems arising from conventional practices include environment and public health (Melero *et al.*, 2005). An organic production system is agrochemical-free, less fossil-fuel dependent (Mendoza, 2010; Mc Laughlin *et al.*, 2000) an environment-friendly system of farming that makes the best use of local natural resources for sustainable agricultural production (Badgley *et al.*, 2006, Mendoza, 2005). The Food and Agriculture Organization (FAO) regards organic agriculture as an effective strategy for mitigating climate change and building robust soils that are better adapted to extreme weather conditions associated with climate change (Mendoza, 2010; IPCC, 2019). Farmers should now shift their production systems from agrochemical-intensive to minimal or even zero use of agrochemicals (chemical fertilizers and pesticides), and adopt farm practices that rebuild the soil leading to balanced agro-ecosystems, or minimal agro-ecological stresses (Badgley *et al.*, 2006; Magdoff and Weil, 2004). This is very timely considering agrochemical prices had more than doubled or tripled in some cases. There is no guarantee that prices will fall to lower levels even if the Ukraine war will soon be over.

An agrochemical-dependent food production systems is unsustainable and risky. As shown in the current looming food crisis and food prices surge: As fertilizer supplies dwindle, a global food crisis looms (Byjoel, 2022). Major food producers: Brazil, Argentina, US, Europe not to mention Russia and

Ukraine, all expect yield declines. Fertilizer-addicted and starved soils of the world are expected to yield lower without sufficient nutrients applied (Mendoza, 2010).

However, instantly switching to non-chemical or synthetic fertilizer-free agricultural production is not correct as experienced by Sri Lanka. In April of 2021, Sri Lanka's then-president, Gotabaya Rajapaksa, banned synthetic fertilizers and agrochemicals (pesticides and herbicides), forcing farmers to use organic fertilizers so their agriculture will be nature-friendly. Their organic farming went catastrophically bad. Their rice yields declined by 20% that they needed to import (Ted and Shah, 2022). There should be progressive transition from chemical to organic agriculture (Montemayor *et al.,* 2021).

Using biologically based regenerative practices in organic agriculture, if practiced on the planet's 3.5 billion tillable acres (1.46 B ha), could sequester nearly 40 percent of current CO2 emissions (LaSalle and Hepperly, 2014). Global energy-related CO2 emissions remained at 31.5 Gt, contributed to CO2 reaching its highest average annual concentration in the atmosphere of 412.5 parts per million in 2020 (42% higher than when the industrial revolution began). (Global Energy Review 2021 https://www.iea.org/reports/global-energy-review-2021/co2-emissions)

Organic agriculture performs multi-functions, i.e., Carbon Sequestration, 4 F's (food, feed, fiber, fuel), Economic functions (livelihood, employment), and Hydrologic Functions (cycling, cleaning/freshening water.

→ In 2018, global emissions due to agriculture (within the farm gate and including related land use/land use changes) were 9.3 billion tonnes of CO2 equivalent (CO2eq).

→ Methane and nitrous oxide emissions from crop and livestock activities contributed 5.3 billion tonnes CO2eq in 2018, a 14 percent growth since 2000.

→ Livestock production processes such as enteric fermentation and manure deposition on pastures dominated farm gate emissions, together generating 3 billion tonnes CO2eq in 2018.

→ Land use and land use change emissions were 4 billion tonnes CO2eq in 2018, caused mainly by deforestation (2.9 billion tonnes CO2eq) and drainage and burning of organic soils (1 billion tonnes CO2eq).

Accounting for carbon emissions reduction by transforming meat based diet to plant based diet

Since there is no available data yet in the literature on the impacts of diet change on carbon emission, it led me to account the carbon emissions reduction by transforming meat diet to plant based diet. The main question to

be answered in accounting for carbon emissions reduction by transforming meat diet to plant based diet is… "*Can carbon emissions be reduced by 50% by 2030 and achieve net zero emissions by 2050?"*
Accounting for the carbon emissions reduction by transforming meat diet to plant based diet is done by the author. Briefly, the procedures adopted were as follows:

1) For greening food consumption
Accounting for carbon emissions reduction by transforming meat diet to plant based diet was done calculating GHG emissions greening consumption. The term used is avoided emission when a certain meat type was not eaten. Below is the equation used.
∑ Avoided GHG emissions greening consumption = (∑Avoided Greenhouse gases emissions from consuming meat) Eqn. 1.
Where:
(∑Avoided Greenhouse gases emissions from consuming each meat type) =
Chicken kg CO_{2eq}/kg x ∑Amount consumed Chicken/year) +
Pork kg CO_{2eq}/kg x ∑Amount consumed Pork/year) +
Beef kg CO_{2eq}/kg x ∑Amount consumed Beef/year) +
Other meat kg CO_{2eq}/kg x ∑ Other meat consumed /year)

Each meat has a different carbon emission value. The meat types include chicken, pork, beef and the other meat types (goat, sheep, lamb, ducks, turkeys, geese). For each meat type, the kg CO_{2eq}/kg are as follows: 31.75, 36.3, 221.63, 29.3 for chicken, pork, beef and the other meat types, respectively. Beef has the highest at 221.63 kg CO_{2eq}/kg. The amounts consumed for each meat type (million tons) for one year (2018) are as follows: 118,110,59.1,62.9 for chicken, pork, beef and the other meat types, respectively. The total amount consumed per year is 350 million tons.

As stated earlier, greening food consumption could not achieve the carbon emissions reduction of 50% by 2030 .Neither could it achieve net zero emissions by 2050, hence, the avoided emissions from greening production was included.

2) For greening food production, the available data on how much greenhouse gases could be sequestered if the world adopted regenerative organic agriculture in 1.46 billion ha croplands (LaSalle and Hepperly, 2014) was adopted. Following organic or non-chemical method; by not using any synthetic fertilizer, the available data was used at 0.7 Gt CO2eq but no data is available in the literature for the global carbon emissions attributed to pesticides. Thus, carbon emissions due to pesticides were calculated by getting

global uses of pesticides (herbicides, insecticides, fungicides) in million tons/year and multiplying their carbon emissions coefficients as follows: per kg herbicides = 6.3 ± 2.7 kg CO2eq; insecticides = 5.1 ± 3.0 kg CO2-eq; fungicides = 3.9 ± 2.2 kg CO2-eq. The formula is shown below:

∑ Pest· GHG emission= (∑herbicides x CO2eq +∑ insecticides x CO2eq + ∑ fungicides x kg CO2eq) …. Eq. 2

The total emissions reduction for agrochemicals was obtained as follows:

∑ GHG emissions Rdxn = (∑ Fertilizer GHG emissions + ∑ Pesticides GHG emissions in CO2eq) Eqn 3

For the total GhGe reduction for greening food production, the formula used is shown: Eq. 4.

∑ GHG emissions Rdxn greening food production = [∑Greenhouse gases sequestered + ∑ Agrochemical GHG emissions Rdxn in CO2eq. in Eq. 3.

The sum of greenhouse gases sequestered in regenerative organic agriculture worldwide was adopted from LaSalle and Hepperly (2014).

The results of the calculations made through Equations 1 to 4 are shown in Table 1.

Table 1. Carbon emissions reduction by greening production and consumption

A. Greening production		**GhGe(Bt)**	
1.Organic agriculture in 1.6 Bha		CO_{2eq}.	
sequester 40% global GhGe (1)	0.4	12.600	40.00
2.Carbon emissions reduction due to A + B		1.054	3.35
a. No synthetic fertilizers(0.7 Gt CO_{2eq}) 13%		0.700	2.22
b. No Pesticides (70% rdxn)	43.4	0.354	1.12
TOTAL (1 + 2)		13.654	43.35
B. Greening consumption (Avoided emissions)			
Consumption per year per meat type			
Chicken --> 118 million tons	118	3.747	11.89
pork --> 110 million tons	110	3.993	12.68
beef --> 59.1 million tons	59.1	13.098	41.58
Other meat	62.9	1.843	5.85
Total emissions avoided for meat		22.681	**72**.00
TOTAL (A+B)		36.335	115.35
Global CO_2 emissions = 31.5 billion tons			
Total meat consumed = 350 million tons			
GhGe(Bt) Greenhouse gas emissions in billion tons			

For greening consumption/ transforming meat based diet to plant based diet, the avoided emissions from no-meat consumptions is 22.681 billion tons CO2eq (72%). While beef consumed is only 59.1 million tons, the carbon emissions per kg beef is 221.63 kg CO2eq, hence the highest at 13.098 billion tons CO2eq.($42%). Not consuming chicken at 118 million tons and pork at 110 million tons led to an avoided emissions of 3.747 billion tons CO2eq.and 3.993 billion tons CO2eq., respectively. And for the other meat, the avoided emissions at 1.843 billion tons CO2eq due to non-consuming 62.9 million tons their meat.

Greening production via adoption of regenerative organic agriculture could sequester 40% of global CO_{2eq} (@ 31.5 billion tons) if done in 1.46 billion croplands and the avoided emissions of 1.054 billion tons CO_{2eq} from non-use of synthetic fertilizer and pesticides, the 2 agrochemical inputs in conventional chemical agriculture. The sum of the 2 values (CO_{2eq} sequestered and CO_{2eq} emissions) avoided is 13.654 billion tons CO_{2eq}. (42%)

Greening food production and consumption yielded an avoided or reduced emissions of 36.335 billion tons CO_{2eq}. which is 15% higher than the Carbon emissions of 31.5 billion tons CO_{2eq}. in 2018. It suggests that there is net carbon sequestration.

But 100% greening food production and consumption cannot be done in one year. Thus, 5 sensitivity scenarios (Table 2) were done as follows:

Scenario 1: 100% Green Production and No beef consumption gave 26.75 billion tons CO_{2eq} equal to 84.93% avoided or reduced emissions equivalent from Global CO2 emissions = 31.5 billion tons.
Scenario 2: 100% Green Production and 50% less meat gave 24.99 CO_{2eq} equal to 79.35 avoided or reduced emissions equivalent.
Scenario 3: 100% Green Production and 70% less meat gave 29.53 CO_{2eq} equal to 93.75 avoided or reduced emissions equivalent.
Scenario 4 is 100% Green Production and 50% less meat gave 31.8 CO_{2eq} equal to 100.95% avoided or reduced emissions equivalent.
Scenario 5: 70% less meat+ 70% Green production gave 19.97 CO_{2eq} and 63.41% avoided or reduced emissions equivalent.
The goal of achieving 50% carbon emissions reduction by 2030 can be achieved in Scenario 5: 50% less meat +50% Green production.
Net zero emissions by 2050 can be achieved in Scenario 4:100% Green Production and 80% less meat.

Table 2. *SENSITIVITY scenarios*: Greenhouse gas emissions reduction (billion ton)

SCENARIOS	GhGe (B ton)	% Rdxn
Scenario 1:100% Green Production and No beef	26.75	84.93
Scenario 2:100% Green Production and 50% less meat	24.99	79.35
Scenario 3:100% Green Production and70% less meat	29.53	93.75
Scenario 4:100% Green Production and 80% less meat	31.80	100.95
Scenario 5: 50% less meat +50% Green production	18.17	57.68
Scenario 6: 70% less meat+ 70% Green production	19.97	63.41
GhGe-Greenhouse gas emissions reduction in billion tons relative to the total GhGe = 31.5 Bt (2019)		

In both scenarios 4 and 5, the adoption of green consumption (50% or 100% no meat consumption) implies that huge tracts of lands for pasture or grazing are freed where trees and carbon sequestering vegetation through photosynthesis are left (Follett *et al*., 2001). The total carbon sequestration will be increasing every year . Even if only 50% of the global pasture lands will be freed from grazing untouched (3.5Bha /2= 1.75 Bha) , the potentially carbon sequestered per year in the soil is already 10 to 15 billion tons, 20 to 30 years after .This will be about1/3 to 1/2 of the 31.5 billion tons CO2emission in 2018(Table 3).

Table 3. Carbon sequestration in pasture lands when cattles(animals) are no longer grazing

C sequestration						
in pasture lands/ha	0.125	0.466	Ton per year			
Gobal pastures (3.5 Bha) Bton	0.4375	1.6314		Cattles/animals are not grazing		
C sequestration year	Billion ton		Mean	50%	60%	70%
10	4.38	16.31	10.34	5.17	6.21	7.24
20	8.75	32.63	20.69	10.34	12.41	14.48
30	13.13	48.94	31.03	15.52	18.62	21.72

** Calculated from Folley et.al 2001 data . USA 236 Mha pasture lands*

C sequestered ranges from 0.125 to 0.466 tons CO2 eq. per ha per year

C sequestration in 3.5 Bha = C seq.in pasture lands/ha x 3.5 Bha

Also, the 50% or more grains grown and fed to animals have corresponding land area reductions that could be grown to wood trees or fruit trees.

The 50% reduction in pork and chicken and the very minimal meat Planetary health diet (86% reduction in meat) will lead to considerable

reduction in the use oil based agrochemicals inputs (fertilizer +pesticides). As shown in Table 4, the carbon emission reduction attributed to non use of fertilizer and pesticide to grow grains for pork and chicken would be 0.28 billion tons per year or 2.8 billion tons after 10 years and it can be as high as 4.7 billion tons of carbon emission reduction after 10 years in the planetary health diet which will reduce meat consumption by 86%.

Table 4.Reduction in carbon emission of(A) 50% no meat diet and (B)86% redution in Planetary health diet *

	Fertilizer	Pesticides	Btons
A.50% No meat diet	0.1875	0.089	CO2e Rdxn
50% rdxn in F+P			0.28
B.86% No meat diet (Ph	0.32	0.15	
86% rdxn in F+P			0.47
* Calculations based on data used in Table 1			

Greening food production and consumption yielded an avoided or reduced emissions of 36.335 billion tons CO2eq. which is 15% higher than the carbon emissions of 31.5 billion tons CO2eq. in 2018.

The adoption of green consumption (50 % no meat) implies that huge tracts of lands for pasture or grazing are freed where trees and carbon sequestering vegetation are left. Even if only 50% of the global pasture lands will be freed from grazing (3.5Bha /2= 1.75 Bha), the potential carbon sequestered per year in the soil is already 10 to 15 billion tons of CO2 eq. The carbon emission attributed to non use of fertilizer and pesticide to grow grains shall lead to 2.8 billion to 4.7 billion tons of carbon emission reduction after 10 years. Freeing 50% of the 3.5 billion pasture lands shall lead to 10-15 billion tons of carbon sequestered via photosynthesis plus the 2.8-4.7 billion tons CO2eq . avoided emissions summed up 12.8 to 19.7 billion tons CO2eq. (10 to 15 +2.8- 4.7) or 40.64%-62.5% reduction . In Table 1, the 50% greening consumption and production (57.68 % reduction in the avoided Carbon emission) and adding 40.64%-62.5% totalled 98.32% - 120.18% carbon emission reduction. An early net zero emission is achieved by 2033 and not 2050.

The current CO2 eq. is more than 400ppm while the goal is 350 ppm (so not to exceed 1.5 deg.C increase in global temperature). It is possible to achieve not only net zero emissions but also net sequestering human living through organic farming and adopting plant-based diet or planetary health diet and at most vegan-vegetarianism.

Synthesis

1. Greening production or shifting to low-carbon-emitting food production systems (organic or regenerative agriculture, biodynamic farming, permaculture, ecological agriculture and more recently, agroecology-based agriculture) leads to lesser energy use and energy footprint. Organic agriculture is not only zero-carbon-emitting but carbon-sequestering (up to 40%) through the aboveground and belowground biomass by sequestered soil organic carbon (SOC).
2. A consumption-led greening of FOOD systems requires consuming less-and-less meat, and minimizing food wastes. Reducing meat intake by 50%, the world can feed 20B (pure vegetarian 40B). It can free about 2.5 billion hectares land that can be devoted to afforestation, reforestation, agroforestry. This shall sequester back carbon emitted via plant photosynthesis. It can pave the way to massive adoption of organic agriculture as the yield reduction during the transition stage can be offset with the reduced demand of feed grains for animals.
3. Our own calculation showed that it is possible to achieve not only net zero emissions but also net-sequestering humans living through organic farming and adopting plant-based diets and at most vegan-vegetarianism.

Climate change is diet change. Less and less meat is the way to rapid shift to organic agriculture.

4. Being resource use intensive and high in GHGe food consumption base, a meat-based food is not a diet for all as poor people will be priced out. Greening consumption through plant-centric diet is an inclusive diet or diet for all! Thus, an accelerated shift to plant-centric /planetary health diet will not harm us and also Mother Earth is urgently necessary.
5. Using cereals as animal feed and biofuel are the twin threats to global food security as they reduce the grains available for human consumption. A meat-free diet is vital to save the world from hunger, food poverty, and the worst impacts of the climate crisis.

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(Received: 25 September 2022, accepted: 28 February 2023)