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Urbanization-Induced GHG Emissions: A Review on the Role of Agri-Food Systems

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Abstract

Agriculture and the food system ramifications account for around 30% of global anthropogenic greenhouse gas (GHG) emissions. Yet, beyond the usual urban food-related metabolic approaches to carbon emissions (globalization of diets, value chains, nutrient balances, etc.), additional structural and spatial dimensions to the conception of this problem need to be outlined. This study proposes a transdisciplinary and multidimensional framework to support the interpretation of food-related GHG emissions induced by different aspects of urbanization; this was done through a bibliographic review considering a broad sample of studies while identifying leading authors and schools. Two major categories of scholarly praxis were used: urban metabolism and urban morphology. In this process, it was found that there is a gap between the perspectives of urban planning and design outlets and the research programs derived from the fact that the urban metabolism stream of studies is simpler to isolate, fund, and implement when compared to the remarkably long-term oriented planning needed to embark on urban morphology measures. Moreover, there is currently a biased tilt toward urban studies in terms of research investments and cases such as the agropolitan territories have been disregarded despite their already proven results. This could be solved if when using the term urbanization, it is understood that de-ruralisation is an inevitable, and simultaneously occurring mechanism. It then follows that urban spatial planning should also be complemented by rural spatial planning to achieve effective integrated solutions within relevant rural-urban science-policy interfaces.

Keywords

Food System, Carbonization, Urban Morphology, Urban Metabolism

1. Introduction

At certain stages of development, economic growth and rapid urbanization are

visibly intertwined and are two positively correlated factors (Dogan & Turkekul, 2016); this is more acute in countries undergoing steep processes of mainstream modernization. This has been conceived as an unchecked and unbalanced process of development that has resulted in ever-increased rates of greenhouse gas (GHG) emissions (hereinafter referred to as emissions or carbon emissions) (Liddle, 2014; Poumanyvong & Kaneko, 2010).

More than half of the world's population already lives in cities, and another 2.5 billion are expected to move to cities by 2050 (UN, 2018). The United Nations Human Settlements Programme reported that the highest growth rate between 1995 and 2015 was clearly in the least developed parts of the world with Africa being the most rapidly urbanizing region, followed by Asia. Nonetheless, Asia accounts for the most people living in urban areas in absolute numbers (48% or around 2 billion people[1]).

Even more important is the fact that currently, the topmost populated 600 cities, accounting for a fifth of the world's population, generate 60 percent of GDP and a comparable aggregate of emissions globally (UN-Habitat, 2016). The important factor to point out is the historical linear revival of the city in recent centuries and as David Satterthwaite et al. (2010) explains, two factors are to be considered: the rapid increase in the number of large cities and the historically unprecedented size of the largest cities.

International institutions and global conferences have set a long-term goal to achieve a carbon-neutral world by 2050. Reportedly, the transition to this carbon neutrality starts by gradually replacing all existing productive assets and structures toward a net-zero carbon economic model, simply expressed by the green premium costs measuring tool that Bill Gates coined in his 2021 book (Gates, 2021) on the subject. Concerning this, in 2022, McKinsey & Co. reports that expenses for the transition of physical assets to net-zero emissions would entail a global budgetary need of US$ 9 trillion on average per year, or 7% of the world's GDP.

Depending on the source, the food system is responsible for between 25 and 42% of the world's anthropogenic emissions (Crippa et al., 2021), of which around 20% comes from agriculture within the farmgate (FAO, 2020). And with a growing urban population in Asia and Africa, any foresight of decrease is unlikely unless substantial measures are considered. Moreover, although decreasing its global share, the food system along with energy and materials holds equal quantitative importance (Rehman et al., 2022) in urban metabolic intakes. Relatedly, beyond these metabolic concerns, urban morphology (hereinafter referred to as urban form) is raising a growing interest.

Furthermore, some studies (Dogan & Turkekul, 2016; Lehmann, 2012) found that the urbanization processes tend to trigger further national GDP, and therefore GHG emissions growth, a considerable portion of which is related to urban food distribution, retailing, and consumption. This is especially true when in-

[1]https://ourworldindata.org/urbanization.

cluding the food system's wider value chains that entail food, feed, fuel, and fiber and regarding its climatic perjury due to overheating, resource depletion, and carbon emissions (Read, 1997). Therefore, the upsurge in the importance of the food system is propelled by concerns about carbonization, trade, and dietary health-related issues (Béné et al., 2019) as exposed by civil society.

Similarly, The EKC environmental inverted-U curve has been contested in numerous instances by Dogan & Turkekul in 2016, James Ang in 2007, and Jordi Roca in 2001, and there is a widespread assumption that even in earlier urbanization, and early capitalist countries, reduction in carbon emissions is not guaranteed after the threshold is bypassed (Liddle, 2014). Hence, urbanization, and the carbon emissions related to its growth, mutually encounter a limitation, climate change.

Additionally, the most climate-smart cities of today are only showing good results by measures of carbon intensity, and not in total carbon output, because no study has denied that all GDP growth increases overall carbon emissions. This kick-start growth is invariably based on the construction of infrastructure and other high-carbon-producing sectors that peak up with urbanization such as food and energy. This is exemplified by the fact that urban areas contribute to more than 70% of the total energy demand and a corresponding proportion of the world's GHG emissions (Soto & Satterthwaite, 2010).

Beyond this food metabolic approach to urbanization, science has identified structural problems related to urban form (Friedmann, 1985; Ismail et al., 2020) that have a significant impact over food related emissions. This means that to improve the overall appreciation of the short-term prospects of metabolic intake dimensions, structural and spatial dimensions to the conception of urban settlements ought to be posed as well. In this context, the following questions were conveyed in the framework of this study:

- Which aspects of urbanization are affecting agri-food-related emissions and how?
- What elements of the food system could be more affected and have a greater impact on urbanization-related emissions?
- What are the main research gaps and loopholes for this subject?
- How can science deal with urban form propositions in the long term when physical structures are permanent and extremely difficult to change?
- In which areas science-policy interfaces would be relevant?

This study aims at analyzing through a cohesive and exhaustive bibliographical approach the impacts of, and possible solutions offered by, the broader food system concerning the issues around urbanization induced [de] carbonization. It proposes a trans disciplinary and multidimensional framework that support the interpretation of urbanization-induced carbon dimensions for the food system.

The paper starts by exposing its estimation methods in Section 2. In the results of Section 3, we discuss and explore the urbanization-related factors that are affecting agri-food systems. A trans disciplinary framework is presented as

an analytical overlay of the results relative to the role of the food systems in urbanization-induced carbonization while defining research gaps. In Section 4, we proceed to discuss the main elements pertaining to urban form (4.1) and urban metabolism (4.2) with a consideration for a reduced number of references which were deemed to be integral (4.3). Lastly, in Section 5, we draw conclusions and draft ideas about how the food system could intervene in reducing GHG emissions, and open questions for future research perspectives.

2. Estimation Methods

To solve the questions posed in the definition of this paper a bibliographical review was proposed, which means a deep analysis of the existing literature has been carried out until exhaustive conclusions have been achieved.

The study aims at establishing the most relevant categories pertaining to urbanization induced carbon emissions where the food system would be most involved. This is achieved through a bibliographical review of the most pertinent scientific works and their authors outlined in the existing research-based dialectics that were found, although grey literature is also included.

The process of delivering research results was designed by determining the main authors and leading schools, their fluent dialectical processes, the most relevant debates, agreements, and the measurement tools used concerning the target subject.

- Main categories
- Leading authors or schools
- Debates and dialectics
- Measurement tools

Theoretical framework

Once this process reached an exhaustive point, the elaboration of a theoretical framework was suitable. This framework categorizes the relevant factors at stake by contrasting them against the two explanatory variables (urbanization; metabolism and morphology). Lastly, this led to the identification of the main subsets of each category, existing divisions, state of tendencies, knowledge derivatives, and especially research opportunities and gaps.

Contrasting these loopholes with the solutions offered by the technocratic parties proved relevant for a diversity of purposes; from setting forth research agendas to preparing new physical assets for the net-zero transition regarding the food system.

3. Results

3.1. Urbanization-Related Carbonization Factors Liable to Agriculture and the Food System

Depending on the source and the type of analytical frame, agriculture and the food system are responsible for 25% to 42% of the world's anthropogenic GHG emissions (Crippa et al., 2021). Most of the studies on the subject have underta-

ken multifactorial and multidimensional approaches to the question of agriculture induced GHG emissions, especially concerning energy use and material flows from rural to urban settings. In several cases, the findings show that there is counterintuitive evidence that most variables do not respond to widely assumed conceptions. Instead, they seem to respond to public policy interactions in the national-regional rather than the international spectrum.

Additionally, there are intuitive as well as scientific grounds that urbanization-induced climate change has made the food system more vulnerable to the impacts of variability (Thornton et al., 2014). Nonetheless, it is the very food system that constructs the more evident interactions between rural and urban economies and its inhabitants leading to eventual adaptation (Fraser, 2006) and prospective corrections therein emerge. In this sense, approaches that propose balanced urban and agricultural-industrial production systems are scarce and it is in this light that answers will be more easily derived.

Today, several research programs have tested the inverted-U curve theory of the EKC mechanism to see whether it is applicable or not to a given territory or country. A study comprising four ASEAN nations expressed estimations that increasing renewable energy in agriculture decreases CO_2 emissions, while non-renewable energy is positively correlated to emissions (Liu et al., 2017). Therefore, it is evident that under certain conditions entailing good agricultural practices and adequate urbanization public policies, agriculture may already be a positive driver in the Low-Carbon Development (LCD) initiatives. For instance, solar panel water pumps for agricultural production are today used as a universal positive measure in both developed and non-industrialized countries (Hilali et al., 2022).

Concerning area studies, in 2022 Asif Raihan and Almagul Tupeskova found that in Kazakhstan a 1% increase in agricultural productivity and the forested area may lead to reduction in CO_2 emissions by 0.34% and 2.59%, respectively. The same study found that a 1% increase in economic growth, energy use, and urbanization caused an increase in CO_2 emissions by 0.14%, 0.81%, and 1.28%. Nonetheless, in early capitalism countries of Sub-Saharan Africa (SSA) increases in agricultural productivity tend to show comparatively higher carbon outputs as a result of degraded systems not yet capable of yielding technology benefits (Alhassan, 2021). This suggests that assertiveness and universal conclusions will be difficult to draw and will certainly require decentralized research views.

A more evident proof perspective is shown for public policy analysts that demonstrate that China and Brazil are performing better in terms of innovation capabilities regarding carbon emissions when compared to India and Russia. A study on these four BRICS nations found the existence of bidirectional causality between agriculture and environmental degradation. However, Russia and India showed fewer favourable results (Pata, 2021). The author attributes these distinctions to poorer innovation perspectives concerning policy implementation.

Moreover, in a comparative instance of policy outlook, Mehmood and Man-

soor found in 2021 that urbanization is helping decrease CO_2 [by intensity] emissions in China, Japan, and Mongolia, while it is boosting the increase of CO_2 emissions in Singapore, Macao, and South Korea. They advise these countries to reconsider their urbanization policies, especially concerning the promotion of green and renewable energy solutions in their urban settings. It should be noticed that a big part of the energy concerns herein entailed are related to the food system; moreover, in this context, the food system supports this analysis as an explanatory variable. In this sense, food provides two major contributions:

- It is the more taxing in terms of CO_2 (possibly due to volume and frequency of use) and,
- It is the most anchoring element connecting us to the natural world and our human identity and condition.

In a review that addresses the rethinking of China's carbon reduction strategy by the Paulson Institute, five categories were outlined as imperative back in 2015. It is a policy memorandum that advises the country to "rethink its national urbanization strategy" (Paulson Institute, 2015). By 2022, it can be noticed that concrete steps are being implemented, namely the "New Urbanization Model" program, henceforth some positive results have been recorded as expressed by academia (Yu, 2021; Zhang et al., 2023) although with nuances (Sun et al., 2023) The industrial pull factor in China and India represents a determining push element for urbanization whilst there are still hundreds of millions of Chinese and Indian rural inhabitants expected to migrate in the following decades. In this sense, although few studies are counting agriculture and food in their material flow analysis (MFA), Chinese schools have seemingly well-embedded the notion of territorial or rural-urban interactions when it comes to policy propositions.

Regarding classification, studies (Kennedy et al., 2011) have found that two major schools of inquiry have appeared to define urban metabolism, energy equivalents, and mass fluxes. Consequently, there is a coherent analogy between energy (electricity), materials, and other big CO_2 emitters in terms of the agriculture and food system's liability in their metabolic proportions. The mass fluxes measure in the MFA approach appears to be the more pertinent in the case nutrients are considered, however, food could also be counted as energy input. Also, it all depends on who is measuring CO_2 and for what purpose. A supermarket will deal with constant energy, materials, and of course food demands, aside from its initial land and structural installments. In turn, these factors are affected when new immigrants arrive in cities, increasing the overall urban GDP and its emissions.

Once this formal accountability of carbon is set forth, and with no major conclusions extrapolating to the international scenario that can determine overarching or one-size-fits-all actions, further ways to interpret this complex problem have been envisioned. In this regard, two major axes are being used by scholars to analyze the variables exposed in terms of urbanization-driven GHG emissions and other environmental causalities: urban form and urban metabolism.

These two categories are studied to then analyze the central argument of integralist options in later parts of this work. Conclusively, food mostly pertains to matters related to urban metabolism which is highly important in carbon emissions counting. Analogically, urban form deals rather with rural-urban and agricultural land use planning and interactions; but both are effects of respective causalities.

3.2. Transdisciplinary Theoretical Framework

In the process of developing a theoretical framework a diversity of transdisciplinary concerns were raised, and in turn, they provided an overview from which to observe the problem statement from an angle driven by both, spatial urban axes, and urban metabolic food-related intakes. The framework contrasts the main research elements (debates, measurement tools) of the food system against the above-mentioned two pillars of urbanization.

Table 1 is proposed to theoretically visualize the major tendencies and subjects at stake concerning the research epistemological model. This means that equal importance is given to the two major areas of scholarly inquiry in consonance with the main conclusions derived from this research project.

As evidenced by the framework in Table 1, two concerns related to the primary sector appeared, on the one hand, rural development is a spatiotemporal frame and, on the other hand, food as a material flow analysis about urban metabolism scrutiny. However, the positions that treated the subject of spatial dimensions to address food-related emissions were more reduced and restricted to Asian references, and if made for Western cases did not involve urban form inquiry. A number of them belong to studies made by geographers, architectural schools, and other urban design outlets for applications. In addition, the agropolitan territories first suggested by John Friedmann (1979) seem to prevail where there is a higher interaction between human communities and rice-producing agrosystems, therefore in societies that historically gave more cultural prominence to agriculture.

Additionally, the nature of the subject suggested that urban structural aspects are to be studied from a top-down perspective while the metabolic aspects are to be viewed from a bottom-up stance reflecting a need to consider power dynamics. However, although it is seemingly the case, it cannot be concluded, as some authors are implicitly or explicitly suggesting (Kolkwitz et al., 2022), that urban metabolism is a dependent variable of urban form.

It is important to understand that within the studies of urban metabolism and form, only a small proportion of authors and schools are focusing on how to challenge the prevalence of the city as the main driver of economic development. This is why one of the main conclusions and singularities of this work is that although some authors have distinguished that urban form is to be integrated (Kennedy et al., 2011; Soto & Satterthwaite, 2010) in propositions as an applicative framework for city design, our conclusion, in contrast, is that both, metabolism and form are equally causal categories with intertwined effects.

Table 1. The food system's sustainability and urbanization research categories.

	Urban form	Urban metabolism
Main categories	Centralized cities Polycentric cities Linear cities Agropolitan territories	Urban agriculture Food and nutrients intake Supermaketisation of food Commoditization of food
Leading Authors or schools	Authors - John Friedmann, USA - Peter Calthorpe, USA - Peter Messerli, Ch Labs, schools or groups: - Future cities lab, Ch - ROBUST group, EU - PLES*, China	Authors - Christopher Béné - Christopher Kennedy - David Satterthwaite Schools Human Geography, Utrecht University
Debates	Rural [and urban] development - Land use change, rural-urban dichotomy - Time geography through digitalization - Urban shapes - (no debate on non-urban solutions)	Food as a material and nutrient flow: - Westernized Asian and global diets - Nearshoring of value chains - Nutrient balance
Measurement tools	City form perspectives in comparative basis. - Extreme complexity to measure performance of the main categories. - Calculations on the suitability of other forms has a better fit in scaled experimental sites**.	Mass fluxes: - Material Flows Analysis (MFA) - Substance Flows Analysis (SFA) Nutrient balance flows - Energy equivalents - Energy flows accounting

*Producing, Living, and Ecological Spaces; **Scaled cities to study urban form and metabolism are reported in Japan. No other site samples concerning urban form were found. Source: made by the author.

Henceforth, one of the main findings in this theoretical frame is that urban form needs to be more conspicuously included in the experimental designs of food-related GHG emissions studies, and other materials and fluids for that matter. This negligence likely derives from the fact that changes in urban form would require long-term planning and robust budgets, and it also requires further analytical perspectives that entail yet another level of multidisciplinary attention.

4. Discussion

The food systems of today are complex, internationalized, and generally ur-

ban-centric. The more the urban-rural gap increases the more complexified the food systems seem to express as urbanized consumption patterns get more diversified and demanding. In this review, we will first discuss on the categories of discussion by describing sectorial-based scientific elaborations and interactions between them, and the environmental disruptions they provoke. Secondly, it is recognized that the majority of studies subscribe to two areas of analysis, urban metabolism, and urban form, and we discuss on the ways these two axes impact the agro-food systems of the world. Lastly, integrated approaches are discussed filling the space left by science through the city design technocracy.

4.1. Urban Form

Urban form or morphology refers to the physical assets that are related to permanent stocks of urban infrastructure such as land used for roads, housing blocks, highways, and the overall area covered by densely spread human activity. As per exclusionary concerns, if referred to **Table 2** in the next section and for this study, all that is not included above buildings belongs to the urban form spectrum.

From ancient history until today, urbanization could rarely be classified as a formal process where governments decide to increase or stop the number of urban dwellers, although there is policy implementation on the record in this regard (Silvers & Crosson, 1980). A country′s spatial population distribution responds to geographical and historical patterns of economic development. Planned cities and rural-urban population displacements are an off-type rather than the norm.

In contrast, central or late capitalism nations put the subject on hold since they have reached not only a high level of formality in housing but also their population growth has stagnated thus focusing more on urban metabolism than on urban morphology. Additionally, disorganized migrations, and therefore housing informality, prevail in the global south, especially in the cities of South Asia where such informality is being exploited (Porter et al., 2011).

4.1.1. Competition for Land between Agriculture and Urban Spaces and Its Impact on Decarbonization

In this study we observe that integrated and transdisciplinary focus is rather the exception and certainly not the norm. Nonetheless this reduction is needed to be able to isolate categories. The food system entails a privileged stance in the rural-urban interactions that are built by the participation of both rural and urban actors, such as peasants and low-income city consumers in Curitiba and Sao Paulo (Forster et al., 2015); a fact that makes the subject ever less readily available for specific research projects at the micro-local level such as disputes over land use, or soil quality.

Concerning land use, authors argue that there is much to be gained by rethinking urban development patterns, especially mitigating global environmental change by changing urban land-use policies (Etherington & Jones, 2009;

Table 2. Classification of urban metabolic intakes by perishability.

Type of CO_2 emitter	Fluidity	Perishability	Outflows
Materials for buildings	Long term fixed	Usually one time	No
Transportation devices	Mid-term fixed	10 to 15 years	Yes, waste
Materials (living/industry)	Fixed	Varies, mid term	Some, exports
Food	**Short term**	**Daily intake**	**Yes**
Water	Short term	Hourly intake	Yes
Energy	Fluid	Immediate	Yes
Fuels	Fluid	Immediate	Yes

Source: made by the author.

Andersen et al., 2011; Luo et al., 2018). Moreover, the studies suggest that for urban lifestyle to be sustainably possible, interfaces need to be drawn between the lines derived from the food system and forestry or what is known as nature-based systems. Land use and soil quality are the key words that should not be taken for granted by innovative urban designers to address the enormous challenges they face in proposing new paradigms of urban organization with LCD and the net-zero transition as background targets. As counter measure, in our frame of analysis we found that agricultural land use should also be a focus of science, in the same way urban spaces are being targeted.

The subject of competition for land between the development of rapidly and newly urbanized areas and the agriculture-producing zones that surround the cities has also been raised as an important element since forces pushing the appearance of productivity increases are now more evident. On the one hand, urbanizing industry flourishes near the already overly populated flat lands within river valleys and coastal shores, and on the other, this very urbanization process increases food demand thereby furthering constraints for the food systems and the environment as a whole. In 2019, Barthel and colleagues argued that more demands over food quantity and quality appear with urbanization, which means more land is needed for what was lost to the city provoking a direct competition between agriculture and urbanization.

One of the main concerns in this regard is that urbanization is a major driver of land use shifts as the planet's population is expected to live in urban areas by two-thirds in 2050 (UN, 2005), or an additional 2.5 billion. Meanwhile, other land-use competitors also appear such as transportation infrastructure, biomass production, and leisure, all derived from, and brought by, general economic prosperity. However, urbanization remains the biggest competitor. To be more precise, in 2016 Cristopher B. d'Amour argued that twice the amount of land that is lost to urbanization is thenceforth needed to replace it, mainly because the quality of the soils in Urban and Peri-urban Agriculture (UPA) is higher and it is poorer in the outlining rural space. However, from the food system perspective rich nation cities that lose land to agriculture can replace it through food

imports from cheaper or more competitive food-producing nations such as Brazil, Australia, or New Zealand.

Additionally, research undertaken on the subject of competition between land use for food production and urbanization raises the notion of urbanization not emitting more GHGs to the ecosystems after a certain threshold is reached. This is also explained by the EKC inverted-U curve thesis discussed previously (Kaika & Zervas, 2013) that enshrines a "*grow now, clean later*" spirit, a hypothesis that has been recanted in a number of studies over the last decade (Gill et al., 2018). The studies that have prevailed seem to dictate that the EKC inverted-U theory cannot be seamlessly extrapolated to all circumstances, countries, or regions of the world. At least not entirely as initially proposed.

Therefore, the question of space competition refers to the immediate adjustment applied over the base of food systems, but it also has implications in longer-term ecosystem potential malfunctions that would hinder the entire cycle of food production possibly irreversibly. Researchers and the design sector agree that there is much to be gained by rethinking urban development patterns and especially mitigating global environmental change by changing pattern of urban land use (Soto & Satterthwaite, 2010).

Likewise, a significant deal of importance is also bestowed on the effects this kind of competition has over both urban and rural spaces in terms of its environmental footprint. Numerous studies are tackling the real impact of urbanization on carbon production per capita and communally, and this cannot possibly be standardized to all circumstances in most nations as we have already discussed since deterministic conclusions are hardly obtained. For instance, the same parameters when paired in multidimensional functions are not showing similar results as in Kazakhstan (Raihan & Tuspekova, 2022) as opposed to Indonesia (Prastiyo et al., 2020).

Nevertheless, from a global outlook, a robust number of authors are suggesting that shaping the spatial development of urbanization growth can prove decisive to strike balance between the resilience of agro-ecological systems and urban sustainability (Samuelsson et al., 2018). In this context, the high-quality soils in which urbanization is thus far happening must be protected as cities that attracted industry and workers were forthwith enhanced by creating wealth derived from higher yields in agriculture.

Most megacities have attracted citizens because of their ability to provide affordable food, availability of water, and work opportunities, a pathway that started with high-yielding agriculture that, in turn, supported the development of construction and industry in later stages of development. But today, the loss of high-quality soils has called the attention of research because the mathematics behind the equation about food needs for the future, and the perjury caused by climate change does already look negative today (Creutzig et al., 2019). As a response a number of cities (Medellin, Barcelona, Milan, and Vancouver) have embarked in initiatives pertaining land protection for the sake of reliable food

systems, and most imperatively, food security (Forster et al., 2015).

4.1.2. Urban form Alternatives: Polycentricity, Agropolitan Territories

Since academia has concluded that extreme urbanization might lead to further overall damage to the world's climatic balances a stream of studies is addressing inquiries related to the spatial distribution and morphology of the new cities. Their scientific outcomes are being considered during the past decade as the call for these actions is imminently and urgent. Equally, a big number of institutions are dedicating financial funding to future city experimental laboratories seemingly building beneficial science - society networks.

This phenomenon has sprawled different ways to address the question of rapid urbanization with many architectural design laboratories already designing futuristic urban matrix models that intend to solve the problem frameworks. For instance, the network city theory used by Steffen Lehman in 2012 supported its findings by developing a comparison study between Shanghai and Berlin's Potsdamer Platz area.

Similarly, other researchers are proposing a halt to rapid urbanization by creating an alternative model in which an urban network of smaller cities surrounds the megacity (i.e., Delhi, Dakkha) thus decentralizing the core by allowing new arriving immigrants to live in smaller cities. These immigrants (former farmers) in this new network city will continue to be either farming entrepreneurs or part of the agricultural labour force while helping maintain high-quality soils in the agri-food sector (Holt-Giménez et al., 2011), and on the other hand, enjoying the benefits of decentralized services of urban life. Examples of these models are being on implementation phases in Asia for at least two decades (Ahmad et al., 2012; Ismail et al., 2020) and it is perhaps time to think whether it will now be a positive fit for the decarbonization targets set worldwide.

The model of sub-centres within polycentric city structures in the global south is discussed by Professor Peter Messerli who draws attention to future city laboratories that are carrying out design programs about alternative urban form modalities and *agropolitan* territories at a praxis level. Thereupon, some megacities around the world are setting up network models to buffer their own urban growth, especially in the advanced industrial economies and in new emerging industrial powers. This stream of research focuses on transdisciplinary analysis and embodies urban designers, and [European type] territorial governance conceptions in a sort of planning that can be negotiated with bottom-up entanglements at the *agropolitan* district level (Friedmann, 1985).

On the other hand, the debate was first exposed by the world city hypothesis (Friedmann, 1985) which provoked a series or reactions in the academic world and triggered a dispute between the observations concerning the international centrality of the city and the widely accepted world system thesis developed by Emanuel Wallerstein (Korff, 1987), during the same period of time, in the early 1980s.

However, today, as the world is embarked in solving the question of carboni-

zation, urbanization and city domination are irretrievably gaining more prevalence. "*Agropolitan* development is a neologism, a new word, a new construct, composed of two elements: the agrarian element and the 'polis' element where 'polis' stands for a democratic and self-governing city" as defined by John Friedmann in 1979. This is being used by the Zurich and Singapore based Future City Laboratory to support the design of polycentric city forms and especially its *agropolitan* communities. Nevertheless, it is still unclear in which conditions will its dwellers participate in rural life, have employment perspectives, and particularly their relation to food production and whether this will really have a significant impact for the carbon reduction endeavouring.

The model shown in **Figure 1**, which is forested in some of today's fastest growing megacities, intends to exploit decentralization to halt quality soil losses to urban developments.

In this context, dealing with resilient community-driven solutions presents a smart option for practitioners provided the number of grassroots responses to the matter of food availability. There is a stream of studies that observe experiences of urban and peri-urban (UPA) agriculture quoted from Cuba (Holt-Giménez et al., 2011) and India (Awashti, 2013) that would work soundly in the global south. Although urban agriculture experiences have been successful in Germany and elsewhere in Europe, they are related to past historical events during communistic times and remain rather experimental (as opposed to subsistence driven) leaving the mainstream modernized food system as prevalent. Nonetheless, although modernized food systems are more realistically sustainable and replicable within the mainstream capitalistic investment sector, community-driven alternatives are very often put into the research agendas (Nemoto & Biazoti, 2017; Cinà & Iacovo, 2019; Islam et al., 2004) because of its long-term embeddedness which is mainly fostered by participatory community acceptance. One question remains to be addressed; is it about an expression of survival or are the communities prone to political self-identification due to a perceived detachment from their ancient agricultural backgrounds? The latter could be especially so in highly urbanized, yet highly agrarian societies like France or the United States.

In **Figure 2**, it is determined how even if there are scientific disputes on the curve shapes (inverted U, versus U curves) related to correlations between carbon increases and urbanization, an argument that is central to the estimates of polycentric proposals is not only that the carbon metrics will be reduced with better planning but that there are also cultural dynamics that will positively affect the model (Holt-Gimenez & Shattuck, 2010). Most studies agree that polycentrism help reduce carbon emission while centralized urban spaces do more to increase them, which draws a major conclusion of this paper. In **Figure 2**, the four elements of the food system (production, processing, distribution, and consumption) are led to vulnerability in the centralized urbanization.

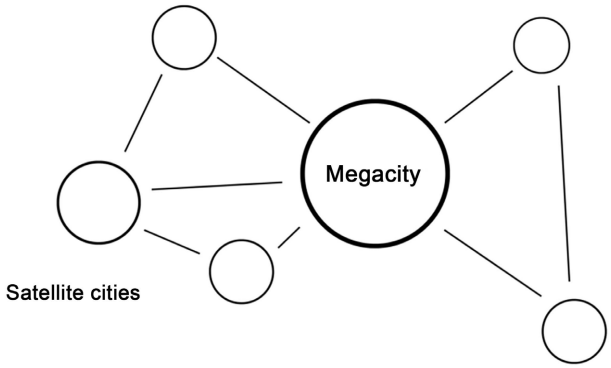

Figure 1. Polycentric urban network prototype. Source: made by the author.

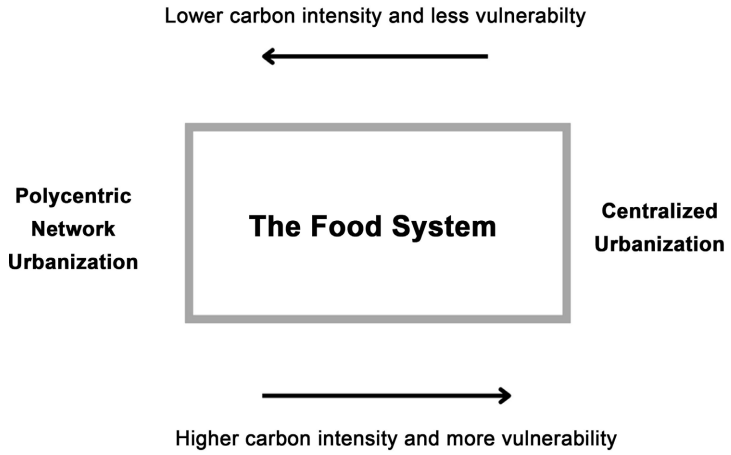

Figure 2. The food system vulnerability to urban-induced GHGs. Source: made by the author.

Peter Calthorpe is also working on compact cities of the future, where spaces are most constrained and dense in terms of population numbers, preventing more urban sprawl not only to protect agricultural land but because it simultaneously saves more emissions from being emitted due to commuting distances. In a way John Friedmann was a theoretician that lived way ahead of his time, and Calthorpe might be in measure to apply some of his views in the United States.

4.2. Urban Metabolism

Traditionally, urban metabolism is studied using material flow analysis (MFA) approaches to breakdown on the physical flows of energy and materials through a city, but other tools and approaches could also be used. Although metrics are not of a particular interest here, they are stated as a useful tool. Food is a particularly flowy material that enters the cities through the food system and exits through several biological processes transforming the human body permanently, and also as waste.

In addition, the food system has undergone impressive changes during the last 50 years, but those transformations did not only bring positive outcomes as stated by Christophe Béné in 2022, who identified the westernization of Asian diets, and the super-marketization of the retail sector as the most important elements critically and negatively affecting the food system. In this part of the study, we establish discussions on both issues, pointing out that the super-marketization of retail is herein expressed integrally by ways of value chain concerns which for the urban consumers is the last echelon in what is seen as a modernizing or westernizer factor of the food system. This is what calls the attention of climate change research and institutional platforms since globalized production systems are remarkably carbon taxing, but this could be challenged as we will observe. Lastly, a thorough discussion on the regionalization of value chains is presented as a matter for analysing the tendencies concerning trade-related emissions and what it would mean for urbanization processes.

As per this section, it is evidenced that the elements of the food system most affected by urbanization induced emissions are distribution and consumption.

4.2.1. Nutrients Balance

One of the prominent subjects concerning urban metabolism is the perspective of MFA or SFA (Substance Flow Analysis) applied to food consumption for that matter. An extensive stream of applied studies on nutrient flows and balances have been carried out to understand the dynamics behind food consumption in cities for both, inflows, and outflows.

To visualize the position of food amongst the various types of materials and fluids flowing into the cities **Table 2** is herein presented. The fluidity of materials and their duration in the ecosystems of urban places are compared, indicating which of these materials stay as short- or long-term stocks in the cities. It is important to acknowledge that anything human-made (city structures) that is permanent falls into the classification of urban morphology and therefore is not addressed in this subchapter, thus displaying the theoretical boundaries of our study.

In **Table 2** water, energy, and fuels could be considered as substances therefore promptly classed in a different light. However, it should be noted that food is closer to substances as its nutrients once processed at the household or organism level become a substance, more related to energy than to any other hard-surfaced material.

Distinctly, a study carried out by Mario Kolkwitz and colleagues (2022) fails to add nutritional flows in what seems a quasi-perfect example of an integrated focus of morphology and metabolism for the case of buildings in Finland. The methods device a way in which sustainability is addressed and measured from the effects of urban form over urban metabolism. Including agritechture and urban agriculture in agropolitan style of perspective could be the next step in this kind of instance.

Concerning nutrient flows most considerations do not, and cannot, extrapolate their inquiry by using theoretical categories. Rather, they use detailed metrics with tools such as MFA and SFA, to determine conclusions. For instance, a study by Jens Færge (2001) found that in Bangkok, Nitrogen is liberated as an outflow in a comparable amount to its inflows, but the same could not be said about Phosphorous whose only 40% is lost to the Chao Phraya river. Other studies of a similar nature were carried out (Barles, 2007; Zhang et al., 2022; Beck et al., 2023) equally focusing on nitrogen in and outflows for the city of Paris, Beijing, and Suzhou using historical archives, multiregional input-outputs, and Multisectoral Systems Analysis respectively.

4.2.2. Globalized Asian and World Diets

A subject of analysis that is widely stressed by scholars and research centres tells about the consequences on the food system that globalized Asian diets have (Pingali, 2007), especially regarding meat consumption, the most influencing single factor according to Xin Xiong and colleagues (2022) in a study published in 2022. It is argued that this trend is enhanced by urbanization, acutely affecting the increase of carbon emissions therein termed as Diet-Linked Greenhouse Gas Emissions (or DGHGEs). Because food consumption patterns change in the cities through specialized retail, fast-food, and supermarkets, the demands from farm-to-fork have changed and they are now more focused on protein intake per capita, as well as exotic fruits, and vegetables in lieu of the traditional staple-based diets which are also less caloric and cheaper. Consequently, this is about a demand-driven rather than an offer-driven trend and responds to a process of modernization.

In a discussion currently taking place by some authors, it is determined that the westernization of Asian diets and super marketization of the retail sector, the green revolution, and the homogenization of crops are the elements most affecting the food system at the moment (Béné, 2022). However, a very central critique therein exposed is that multinational corporations, also known as Big Food, should be dissociated for the systems to be sustainable. Comparingly, a more realistic stance is exposed by an Australian-New Zealand research group that tested climate-resilient diets and determined that the Mediterranean diet is the less polluting (Allenden et al., 2022), in what is a more realistic effort to correct the food systems from within the value chains that these corporations operate.

Prominent reference to Asia is highlighted because the magnitude of the impact to climate change will be second to none. This means the food systems of Asia are getting more and more complex, energy-hungry, carbon-intensive, and, in cases of disorganization, highly vulnerable as exposed by Shariful Islam and colleagues in 2004. Nonetheless, there is a notable difference between what is occurring in richer parts of northern Asia, with what is observed in southern Asia. An assumption is that in the process of transformation from a subsistence and traditional to a market-oriented food system carbon emissions increase.

Meanwhile, in China and southeast Asia, meat consumption is expected to

increase beyond the already unprecedented changes during the last three decades in which it bypassed other major regions of the world such as North America or Europe. China will reach 80% of urban population by 2050 (up from 50% in 2000, and 68% in 2020) while today already 80% of food is consumed by urban dwellers (Xiong et al., 2022), more than its correspondence proportionality (68%). The following graphs show the growth of overall meat consumption in China while in *per capita* consumption terms western nations, such as the United States or Brazil, continue to be on top of the list (**Chart 1**).

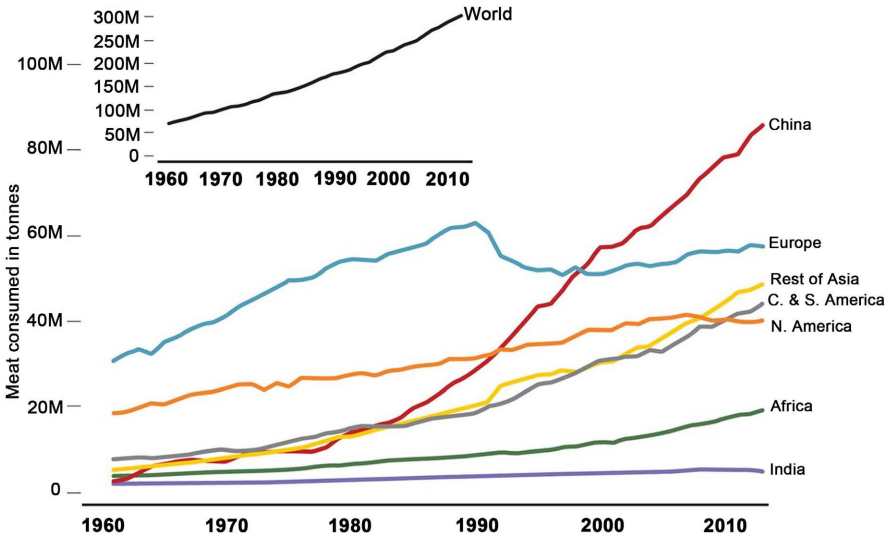

Chart 1. Total meat consumption in different regions and the world (in million metric tons). Source: FAOStat.

In this context, a study that addresses the measures to keep the food system within environmental limits found that if no major changes are implemented the planetary boundaries and capabilities will be exhausted. It also found that no single measure could cope with the systemic pressures and established that three major actions need to be undertaken; 1) dietary changes towards healthier, more plant-based diets, 2) improvements in technologies and management, and 3) reductions in food loss and waste (Springmann et al., 2018). Other reviews have found concrete comparative analysis and are already dealing with market-oriented concerns, especially food consumer preferences with diets that are climate friendly (Allenden et al., 2022).

4.2.3. From Globalized to Localized Supply Chains

The metabolic flow of materials between city and countryside also occurs at the international level; urbanization implies exchanges beyond national boundaries. Rural areas of some countries are feeding urban centres of developed industrialized nations which demand cheaper but also higher quality products that can only be achieved in high availability of [agricultural] labour and most often higher division of labour. However, it is unclear if globalized supply chains are

less sustainable than localized supply chains as exposed in a study by Gianluca Brunori and colleagues in 2016 in the framework of the Glamur research group in Europe. This is confirmed by study evaluating food value chains in Peru and Belgium (Schwarz et al., 2016), but put into a different light by frameworks that analysed territorial short food supply chains (TSFSC) in its contrast to large-scale food distribution (LSFD) (Reina-Usuga et al., 2023).

In this regard it could be hypothesized that production in the industrialized countries will anyways be more expensive [therefore carbon intensive] due to the high level of technology/energy involved in all processes. A number of studies are observing that it is very difficult to isolate the variables at stake when assessing sustainability for local and global value chains. In this sense, Brunori and Galli (2016) stated that a sustainability assessment is not only about measurement methods, but also first of all a field over which different interests, representations, and discourses confront each other.

Therefore, city metabolism cannot be isolated to a local-national urban centric food system, as several products consumed in megacities come from faraway places and they have to be included in the overall LCAs derived from food trade. Although concerning the dispute between local versus global supply chains, with the current post-Covid pandemic trend it will likely lean to localized food chains not because of costs constraints but due to national food security concerns and pressures by climatic goals (Dimmers & Ruben, 2020).

In regard to the bearings of climate change and carbonization over the food supply chains of the world we found two streams of research projects that in bold terms respond to the traditional dichotomy of adaptation-mitigation views. On the one hand, the studies that discuss the ways in which sectorial (i.e. livestock, staples) clusters can help reduce emissions (Porter & Reay, 2016; Mottet et al., 2017; Sazvar et al., 2018) and, on the other, those that elaborate on the way climate change and carbonization are affecting particular supply chains in terms of its functioning and resilience such as coffee (Laderach et al., 2010), livestock (Godde et al., 2021) or fruits and vegetables (Parajuli et al., 2019). One study states that the key actors addressing the subject of carbonization are the supply chain managerial structures (Sazvar et al., 2018). These studies do not generally address on the possibility of, or provide concrete examples, where supply chains have been interrupted and re-localized due to climate change public policy incentives or private sector concerns over its financial viability.

An inherent question that will arise with the potential rise of re-localization of value chains might be whether this re-localization/re-nationalization can embody a tilt toward agroecology and improve agricultural practices altogether meeting the demands of alternative political views.

4.3. Integrated Approaches

In the wake of extreme urbanization in Asia, the Chinese government launched a rural revitalization program that could be, in a way, compared to the European

Commission's approaches to rural development and rural-urban interfaces (ROBUST project). A framework of analysis has been developed and implemented on the premise that there are three prevailing interacting axes: Production, Living and Ecological Spaces (PLES) (Yu et al., 2022) which are interrelated with Main Function Zones (MFZs). The idea was first developed in Taiwan in the 1980s (Zhao et al., 2022). This fact partially answers to the above-mentioned research loophole about carbon reducing agricultural space planning. In this context, it can be observed that architectural approaches to science, and science to design/planning (which is directly influence by public policy), are proving effective in finding transdisciplinary solutions to this now global query.

For a problem of this magnitude integrated studies are providing solutions that are broader in scope and more realistic in terms of their practical applications. In this sense, in 2022, Kathryn Oliver and colleagues (2022) say that the majority of research-policy engagement activities themselves date from 1945 onwards, with a large increase in activity from 2010 onwards and climate change applications are at the top of the list due to its societal relevance. We know that the interaction between science, policy and politics is and will continue to be complex, contested, and contingent but knowledge brokers are key in this process (Kass et al., 2022) and are lacking in our model.

Although the PLE framework approach is highly positivist and based on mathematical methods, its outcomes are contrasted against approaches stemming from the social sciences such as peasant studies or rural anthropology, playing thus a key role in finding integrated solutions. In 2020, a study on peasant relocation decision-making by Zhang et al. (2020) elaborates about the social and economic fabric around peasant families defines their willingness to seek improvements and establishes that whether the rural space can be restructured or not in a given territory is decided by peasants' willingness and ability. This could be extrapolated to the urban migrant settlement's ability to succeed and shows, at the same time, a lack of current focus on the interactions between rapid urbanization and rapid de-ruralisation, two simultaneously occurring mechanisms.

Additionally, in the realm of city design, and more specifically, the polycentric approaches to buffered urbanization, we should observe what is happening alongside the rural world to define better-integrated strategies. In the past Agropolitan territories were proposed in Asia but this tendency seems old-fashion for the new schools and its research agendas.

The observance of the confronting rural sociology theories with the strength that rapid urbanization is bringing in some parts of the world is leading to more questions as new peasantries are rather anchoring human development with our past as a sign of resistance. In this context, a process of deactivation and agricultural industrialization is meeting a re-peasantisation trend as shown in a book written in 2009 by Jan Douwe Vander Ploeg (2009), and this learning continues well in the third decade of the century with the threat of global pandemics effec-

tively recalling the question of urban life again.

5. Concluding Remarks

In the process of implementing this research project, it was found that two major areas of scholarly praxis are involved in the interpretation of food-related emissions in urbanization: urban form and urban metabolism.

There is a division or gap between urban design outlets and the research institutes that possibly derives from the fact that the urban metabolic stream of studies (value chains, urban agriculture, etc.) is easier to isolate, fund, and implement than the elements related to urban form that can only be driven to success through long term planning and robust public sector investments. However, in this research project, it was found that insistent attention to urban form should be integrated into the urban metabolism studies if emissions are to be targeted realistically. This is because urban metabolism cannot always be considered a causality of, or a dependent variable vis-à-vis urban form as intuitively argued.

However, viewed from a spatial demographic perspective it is the process of urbanization that triggers more pressure on the food system, remarkably provoking more availability, more consumption, and thus producing more GHGs per unit of revenue. In this sense, the peri-urban agropolitan territories theory is the more suitable and is an already applied solution, yet it is widely disregarded by current academic debates.

Moreover, there is currently a biased tilt toward urban studies in terms of research investments, possibly derived from a superior stance of the urban as opposed to the rural. Thereon, the city continues to be perceived as more important and deserving of more attention, a fact that further strengthens the very problems it intends to disentangle. This could be solved if when using the term urbanization, it is understood that de-ruralisation is an inevitable, and simultaneously occurring mechanism, and thus has to be tackled simultaneously. It then follows that urban spatial planning must also be accompanied by rural spatial planning to achieve effective integralism.

Currently, a handful of city laboratories of the future seem to be well integrated into realistic problem-solving frameworks such as the agropolitan territories proposals when compared to mainstream urban planning outlets. Conversely, the food system research groups need to get closer to those city laboratory outlets to exchange ideas and draw solutions together. This reveals that there is sufficient know-how to create sound urban-rural systems to ensure subsistence and prosperity.

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