

# Social Contagion in Veganville

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## Research Article

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# Social contagion in Veganville

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## Abstract

Meeting the 1.5°C commitment will mean the per capita emissions need to come down to 2.6 tonnes by 2030. Epidemiological contagion modelling principles are applied to transfer of trending climate conscious food choices. This research applies social contagion theory to explore “reproduction values” and “recovery rates” of vegan diets that have potential to facilitate a climate social tipping point to meet Paris Agreement targets by 2030.

## Main

This research explores the potential for shifts in urban dietary preferences to contribute to meeting the Paris Agreement target of 1.5°C warming in a fictitious city called Veganville. Global greenhouse gas emissions were 6.4 tonnes per capita in 2015 when the Paris Agreement was ratified. Meeting the 1.5°C commitment will mean the per capita emissions need to come down to 2.6 tonnes by 2030. Turning the trajectory downwards requires a change in global behaviours constituting a social tipping point. This research looks at the potential contribution of low-carbon dietary change using social contagion theory at forging a social tipping point for meeting the climate challenge.

It is known that plant-based foods typically generate fewer GHGs than their equivalent animal-based foods (Poore & Nemecek, 2018). Plant-based diets, or vegan diets, are considered a crucial social movement towards global climate action (Detzel et al., 2021). Replacing animal foods with novel plant proteins, such as legume products, and thus broadening the protein market is necessary for increasing widespread uptake of veganism. This is especially true of urban food systems, known as the urban “foodprint”, where wealth is high and matches high animal-food consumption, but where environmentally altruistic values are concentrated (Goldstein et al., 2017). There is a lot of potential for shifting food burdens in cities from GHG-dense food choices. Food choices are often embedded in strongly held belief systems and cultural rites which makes top-down governance unpalatable (Goldstein et al., 2016). However, there is room for encouraging environmentally altruistic behaviour through nudging urban social networks (Dietz et al., 2013; Kalof et al., 1999; Stern et al., 1999).

Solutions range from reducing our consumption, to novel technology used to decouple the economy from its impacts. Regardless of the strategy, materialising the green transition into a low carbon society means crossing a social tipping point (STP). An STP occurs when the collective action of a population reaches leads to wide-ranging systemic change (Milkoreit et al., 2018). The problem is that so far STPs have only been described qualitatively and the mechanisms beyond their emergence remain poorly understood. Exploring these triggers can help determine when changes in elements of the system lead to the crossing of a tipping point and to a different system configuration.

Social contagion, like epidemiological contagion, is a system of agents who transmit by contact with other agents within a connected network (Christakis & Fowler, 2013). As a socially contagious concept gains popularity the number of spreaders increases, resulting in a non-linear trend (Baranzini et al., 2017). When the number of infected agents reaches critical mass a climate social tipping point is reached, for example (Barrios-O'Neill, 2021).

This paper posits that social contagion theory may be useful to leverage climate social tipping points (Lenton, 2014), and thus mobilise society towards meeting global warming objectives (Otto, 2020) in lieu of underwhelming and unfit-for-purpose policy-making.

The way in which the population model is defined allows an age specific flow of contagious ideas to spread amongst the population. Contagion is influenced by the reproduction value,  $r$ , defined as the number of individuals each contagious individual infects per time step (i.e. per year). Unique  $r$  values can be applied to each age cohort can be defined, and adjusted to explore scenarios for high and low reproduction, and mixed reproduction rates between the age cohorts.

Similarly, a variable called fixation rate refers to the recovery rate used in epidemiological contagion models. The fixation rate is the ratio of contagious people who will remain contagious until the end of the time step. This allows the model to be adjusted to explore different thresholds of “stickiness” of ideas for the different age cohorts. For example, younger people might be more willing to adopt an idea (higher  $r$  value) but be interested in the idea for a shorter time period (lower fixation).

Exchange from non-contagious to contagious cohorts is determined by the product of status quo and  $r$  value. Status quo is a variable simply defined as the ratio of non-contagious population to total population. Exchange from contagious to non-contagious is determined by the product of contagious, status quo, and the difference between 1 and attachment. A low status quo value and a high attachment value will result in low portions of the contagious cohort reverting to be non-contagious.

New entrants to the social system, be they new-borns or new immigrants, are distributed into the two cohorts weighted by the status quo. The number of new entrants joining the non-contagious cohort at any given time step is the product of the total new entrants and status quo. This is further distinguished by age cohorts. The remaining new entrants join the contagious cohort, also distinguished by age cohort. A dynamic feature of this approach is that as the status quo changes over time the heaping of new entrants changes too, creating a reinforcing feedback loop. Using this approach we can observe how generational perspectives shift through Veganville’s population, which we expect to be non-trivial as fertility rate descends and this interacts with the aging of Millennials.

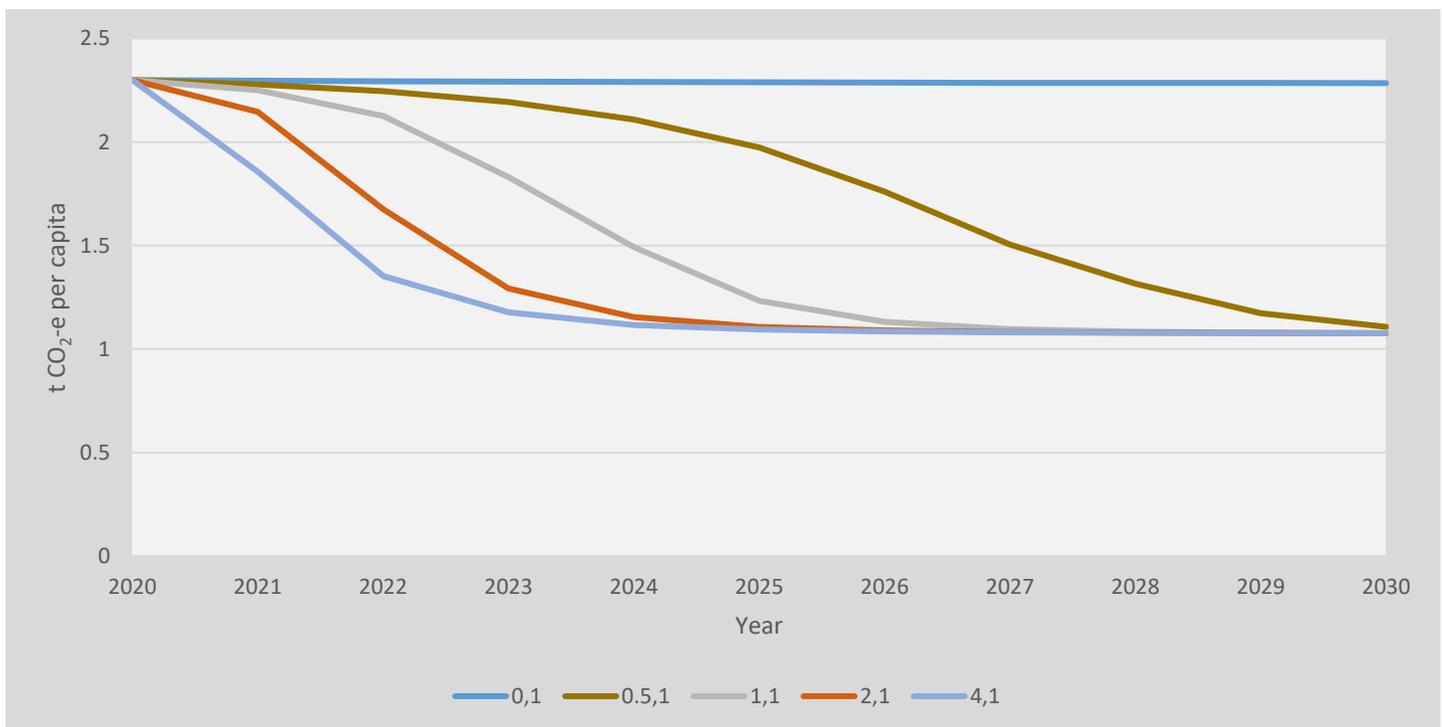
**Results** show that combinations of differing  $r$  and  $f$  values have significant impact on the foodprint over the decade. For  $r$  values 2 or greater, the  $f$  value is significantly less relevant. For example, even for  $f=0$ , the foodprint almost halves from 2020 for  $r=2$ . This is good news for vegan advocates, who can find solace in outreach programmes that are successful at getting people to adopt a vegan diet for only short periods of time. The same, however, is not true for scenarios using  $r=0$  as seen in **Table 1**.

**Table 1** Sensitivity of Veganville’s estimated diet-related greenhouse gas emissions on reproduction (r) and fixation (f) values for the eight age cohorts in 2030. Values in tonnes CO<sub>2</sub>-e per capita. In 2020 the population foodprint averaged 2.30 tonnes CO<sub>2</sub>-e per capita. Lower values are shaded by lightest and higher values are shaded darkest. Scenarios for which the diet-related GHGs increased from 2020 are highlighted with red text.

		r				
		0	0.5	1	2	4
f	0	2.32	2.32	2.27	1.23	1.23
	0.25	2.32	2.31	1.32	1.14	1.13
	0.5	2.32	2.28	1.12	1.10	1.10
	0.75	2.31	1.75	1.09	1.08	1.08
	1	2.28	1.11	1.08	1.08	1.08

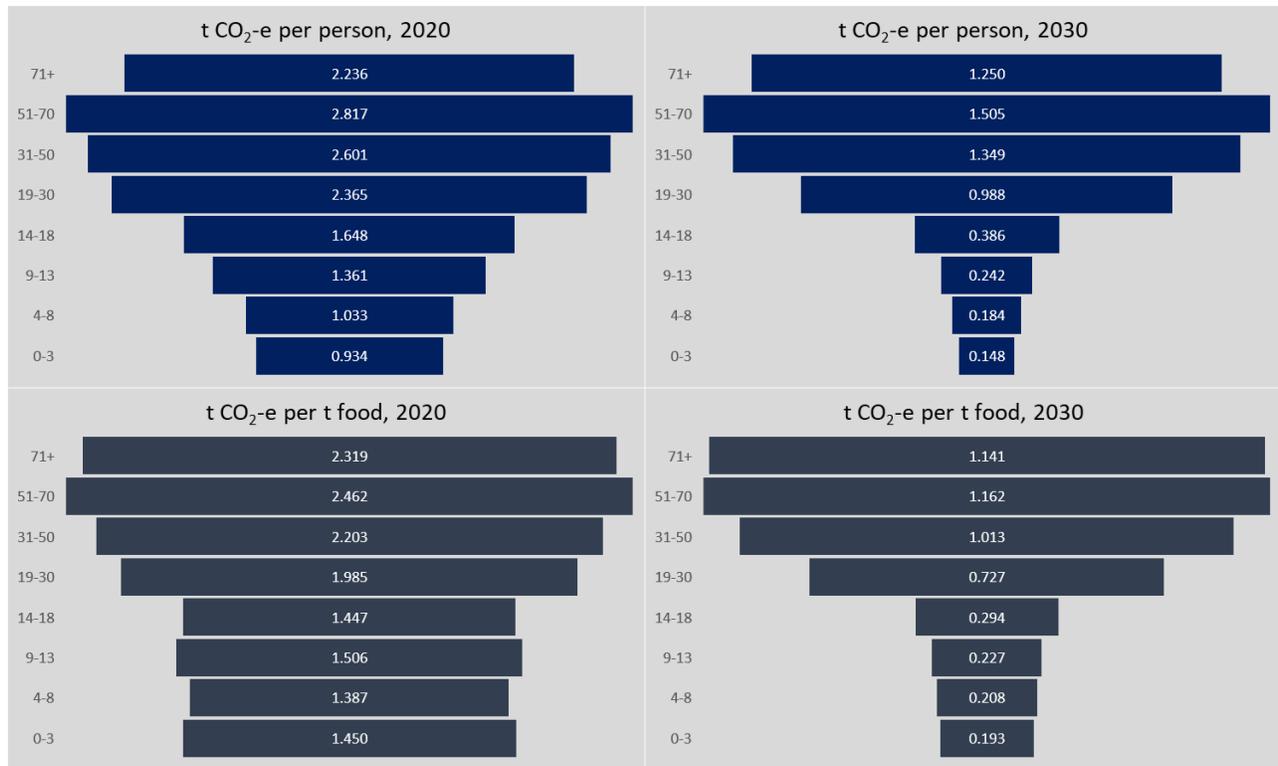
With this exception, doubling r and f value while holding the other constant produce similar gains. For example, if r=0.5, doubling the f value from 0.5 to 1 almost halves the foodprint, as does the converse for f=0.5 and doubling the r value from 0.5 to 1. This linearity is not profound, but the interchangeability between leveraging r and f reveals the focus of change agents is irrelevant.

Foodprint values begin to plateau at around r=1, f=0.5 and tending to a lower limit of 1.08 t CO<sub>2</sub>-e per capita. This amounts to chopping the 2020 foodprint by ≈ 50% over ten years. The problem is that food systems make up approximately 34% of global GHGs (Crippa et al., 2021). Thus, in a best-case scenario there only remains around 1.52 t CO<sub>2</sub>-e per capita to spend on all other activities if we are to meet the 2.6 t CO<sub>2</sub>-e per capita cap by 2030. In other words, the other ≈ 35 Gt CO<sub>2</sub>-e released annually outside the global food system - amounting to around 4.8 t CO<sub>2</sub>-e per capita – must squeeze down to a fifth that amount. **Figure 1** shows curves of foodprint per capita for all f=1 scenarios showing the influence of variations in reproduction number demonstrating the aforementioned lower limit at 08 t CO<sub>2</sub>-e per capita.



**Figure 1** Foodprint per capita from 2020 to 2030 for scenarios with f=1 scenarios for r=0, 0.5, 1, 2, and 4.

Running with this lower limit of 1.08 t CO<sub>2</sub>-e per capita as the best possible outcome, the r=2, f=0.75 scenario is developed further to illustrate the influence vegan contagion has over different age cohorts over time. The foodprint varies by age cohort due to the influence of age on food preferences, and the lag of the model taking longer to reproduce vegan contagion in older people. Foodprint age pyramids in **Figure 2** show how this structure shifts over the decade.



**Figure 2** Foodprint age pyramids showing the age-related t CO<sub>2</sub>-e per capita between 2020 (top left) and 2030 (top right), and similarly t CO<sub>2</sub>-e per t of food consumed in 2020 (bottom left) and 2030 (bottom right).

Shifting away from animal-based towards plant-based diets is a very useful piece in the climate mitigation puzzle. Citizens' agency has high potential to positively influence the climate emergency. Given the reluctance to legislate for climate-friendlier food choices, government-led communication nudging to increase the reproduction value and fixation rate may be a useful solution toward a climate social tipping point (Moser & Dilling, 2007). Nudging up the reproduction value and the fixation rate a small amount will have a profound impact on the decarbonisation of food. Nudging is a method of moving consumer habits towards an objective for the common good, such as decarbonising the food system. In the vegan social contagion case, consumers could be nudged towards purchasing items that substitute animal-based products (Morren et al., 2021), such as communicating through environmental product declarations on food packaging (Vandenbroele et al., 2020) and re-articulating official public dietary advice (Ensaft, 2021). This would have an impact on education leading to shifts in norms and values (Hansen et al., 2021) which would in turn reinforce policies and governance (Otto, 2020).

## Methods

### *Population*

Veganville is a fictitious city of nearly 2 million inhabitants used to develop the plausibility of vegan social contagion propagating a climate social tipping point. Veganville's is modelled in eight age cohorts whose members age through cohorts until death. Death may occur during any cohort membership, but the mortality rate of each cohort differs. Babies are born into cohort 1 while immigrants enter cohorts 1-7, but not the elderly cohort 8. It is assumed only cohorts 4-6 reproduce. Therefore, the dietary characterisation of babies is weighted by that of cohorts 4-6 (i.e. parents choose how the new generation will eat). This indicator is called "status quo". In the case of our hypothetical city Veganville, net immigration rates for each age cohort are data from the agglomeration of Montréal (Ville de Montréal, 2017), where the research took place, while cohort-specific fertility and mortality rates are taken from the Québec Institute of Statistics (Institut de la statistique du Québec, 2021a, 2021c). Initial population count for 2020 was taken from Institut de la statistique du Québec (2021b). Population variables are available in **Supplementary table 1: population**.

### *Dietary profiles*

The dietary change assumes two diet profiles: standard omnivore diet (SOD) and plant-based diet (PBD). The SOD is defined by the average Canadian intake of each food, excluding all specifically plant-based substitutes and by adjusting animal-based foods set to the "eater" value defined in Health Canada (2018). The PBD is defined by the average Canadian intake of each food, excluding all animal-based foods with calorifically-equivalent amounts of substitute plant-based foods. This way both dietary profiles provide the same calories for each cohort. Foods are consumed in different quantities by different age groups. As the age structure of the population changes so too does the food consumption profile of the city. These data are available in **Supplementary table 2: food**.

### *Social contagion*

The model calculates a dietary profile for the city at each time step weighted by the number of adherents to each dietary preference. The number of adherents is calculated using social contagion principles with a reproduction value ("r" value) which allows for an exponential uptake in PBD adherents as the diet becomes more "contagious". When a member becomes contagious they may remain contagious indefinitely (fixation rate, f) or they may recover. The fixation rate is determined by the user as with the r value. R value and fixation rate for each age cohort were varied to benchmark the respective sensitivity in food-related GHGs per capita. Values and variables used for the social contagion model are found in **Supplementary table 3: social contagion variables**

### *Emission factors*

The foodprint of Veganville is calculated for each year depending on the current age structure and adoption of veganism. Food-related GHGs are estimated as the sum of products of mass of each food type and the emission factor (EF) for each food type. The EFs are generated in ecoinvent (Wernet et al., 2016) using "ReCiPe Hierarchist" midpoint impact assessment method (Huijbregts et al., 2017) where available. EFs not available in ecoinvent were attained from literature, including

pasta (Recchia et al., 2019), mushroom (Robinson et al., 2018), ice cream (Konstantas et al., 2019), baby food (Sieti et al., 2019), confectionary (Miah et al., 2018), soft drinks (Amienyo et al., 2013), game meat (Fiala et al., 2020), margarine (Nilsson et al., 2010), and sundry from Poore and Nemecek (2018). The full list of EFs is in the **Supplementary table 4: emission factors**.

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