When Culture Influences Climate Changes: Quantifying the Effects of the Mediterranean vs the Vegan Diet in Italy

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Abstract. In recent decades, the debate on climate change has progressively become interconnected with that on food choices, highlighting how cultural habits can influence the environmental impact of diets. In particular, the Mediterranean diet and the vegan diet represent two distinct dietary models that, although both considered sustainable, have significant differences in terms of greenhouse gas emissions, land use and water consumption. In this paper, these effects were mapped and quantified in order to compare them and to offer an instrument for political decisions, for example for strategies to orientate future habits and consumptions in food.

Keywords: climate change · dietary impact · spatial analysis

1 Introduction

The problem of climate change is becoming in recent years an increasingly urgent issue to be solved, due to the acceleration in its evolution. Among the main recognized causes of these changes there are greenhouse gas and aerosol emissions [1, 2], in parallel with the increasing deforestation [3]. Although the main climate change mitigation policies focus mainly on emissions from the energy sector or the transport sector, the debate on the effects of food choices on these has also grown considerably over the last decade [4]. In fact, there is a two-way relationship between climate change and diet. The diffusion of dietary culture and the adoption of particular dietary habits can contribute significantly to increasing or conversely reducing environmental impacts, because food production is responsible for greenhouse emissions and land and water consumption and this is exacerbated by the problem of food waste. Similarly, the food system is affected by climate change [5], because the increasing of extreme events such as droughts or floods and the spread of diseases on plants and animals reduce agricultural productivity and food safety and quality. For this reason in literature, many papers are recently treating the relationships between climate changes and diet [6–9]. In fact, even considering the future trends of a growing population, together with the consumption and supply of food calories per capita, which in turn has increased [10, 11], it is becoming more and more important for science to direct people's food policies and culture in a direction that could ensure sustainability and global food security.

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O. Gervasi et al. (Eds.): ICCSA 2025 Workshops, LNCS 15894, pp. 3–17, 2026.
https://doi.org/10.1007/978-3-031-97648-3_1

Among the diets most studied for their environmental impact and health benefits are the Mediterranean diet and the vegan diet.

2 The Mediterranean Diet

The Mediterranean Diet is one of the diets considered sustainable since now. It was inscribed on UNESCO's Representative List of Intangible Cultural Heritage in 2010, recognizing it as a timeless nutritional model [12].

This model encompasses practices like crop cultivation, fishing, and food preparation. It includes food like olive oil, cereals, fruits, vegetables, fish and meat and beverage such as dairy, wine and infusions. It is a way of life that promotes social interaction, cultural traditions and respect for biodiversity. The local communities involved are those of regions such as Spain, Greece, Italy and Morocco. Since 2013, those of Cyprus, Croatia and Portugal have also been included [13].

The inclusion of the Mediterranean Diet in the list certainly underlines the cultural importance of a lifestyle strongly linked to the Mediterranean area and too many good practices. While not referring to precise and measurable food claims, such as nutritional tables, it aims to raise awareness of healthy and sustainable eating practices globally. In fact, UNESCO recognition led to the socio-economic growth of the countries involved and established the diet as one of the most sustainable food systems in the world, with the support of the FAO.

The FAO has recognized it as the most sustainable diet due to its reliance on local agricultural products. It is now seen as a symbol of good health and environmental balance, with minimal impact on soil, water resources, and greenhouse gas emissions [14].

The Mediterranean Diet has gone from representing a model of healthy eating to one of sustainability, and has been considered in challenges such as the United Nations 2030 Agenda for Sustainable Development and the European Farm to Fork strategy.

Starting locally to act globally, with a focus on education, the MD is now considered to be closely linked to several UN Sustainable Development Goals (SDGs), as recognized in 2013: SDG 2: Zero Hunger, SDG 5: Gender Equality, SDG 14: Life Below Water, SDG 15: Life on Land, SDG 17: Partnerships for the Goals [15].

Despite its increasing global popularity, adherence to the diet is declining due to lifestyle changes, globalization, and socio-economic factors, posing a threat to its preservation. The challenge now is to reverse these trends and focus on its sustainability as a key model for future food systems [16].

There is debate about updating the food pyramid and adapting it to modern agricultural, economic, and social challenges. A new Mediterranean Diet pyramid has been introduced, aiming to integrate health and sustainability. This updated version reflects the principles observed by the Keys in the 1950s and 1960s. It emphasizes the regular consumption of fruits, vegetables, and whole grains for satiety and reduced intake of processed snacks, contributing to a more sustainable diet.

The major change in the updated pyramid is the position of legumes. Previously considered a secondary protein source, legumes are now recommended as a daily part of the diet. Why are legumes so important?

1. They reduce the need for animal-based proteins, lowering the environmental impact of our diet.
2. Legume cultivation acts as a natural fertilizer by fixing nitrogen in the soil, reducing the need for synthetic fertilizers.

This new model demonstrates that consuming up to one serving of legumes a day can be beneficial for both health and the planet, even within an omnivorous diet, not just vegetarian or vegan ones.

Today, the Mediterranean Diet serves as a model for addressing the challenges of the UN 2030 Agenda for Sustainable Development and the new European Farm to Fork strategy, which aims to reduce the environmental impacts of the agro-food sector. It is seen as a system for building a sustainable future, starting locally and acting globally, with a special focus on education and future generations [17].

Mediterranean diet is considered a system for building a sustainable future, starting locally and acting globally, with a focus on education and future generations. However, Mediterranean diet requests daily diary products, meat and fish. Nowadays it is know that human nutrition has a great impact over the present environmental crisis and that a big percent of the water footprint, of the greenhouse gas and deforestation depends from animal-derived food.

3 The Vegan Diet

The vegan diet is part of what is more generally referred to as the vegetarian diet. Within this there are various subsets of diets: lacto-ovo-vegetarian, if they exclude meat and fish, but include milk and dairy products and eggs; lacto-vegetarian, if they include only milk and dairy products as foods of animal origin; ovo-vegetarian, if they include egg consumption in the diet. In the vegan diet, any type of food of animal origin is instead excluded, including instead a huge variety of plant-based elements (grains, legumes, vegetables, fruits, nuts, seeds, vegetable oils, herbs, and spices) [18].

There are many reasons why people choose a vegan diet: ethical reasons related to love for animals and the principle of non-violence; reasons related to the desire to improve one's health; reasons related to environmental sustainability. On health grounds, the vegan diet has in the past been accused of not being a complete diet and therefore unhealthy. In 2016, however, a position paper by the Academy of Nutrition and Dietetics was published [19], according to which a well-planned and integrated plant-based diet can be suitable for all ages and conditions. Other scientific studies highlight the benefit of the vegan diet (just as some examples see [20–22]). Therefore, as with the Mediterranean Diet, a Veg Pyramid was formulated, with associated guidelines [18, 23].

Also the sustainability of the vegan diet has been deepened and ascertained in literature as well as being a driver of innovation in the culinary field and an opportunity for economic growth [24–30], even, in some models a world completely vegan could be a threaten for agricultural crop leftovers, put more strain on land and water resources, and result in the loss of significant plant and animal genetic components [31].

Because of the increased sustainability that would result from increased consumption of plant foods, several international and local campaigns have been launched around the world, aimed precisely at promoting a reduction in the consumption of animal products.

Some of these have been initiatives of private actors, while others are part of institutional environmental policies:

- the Meatless Monday (promoter: Paul McCartney), consists of reducing the consumption of meat (and in its extended version of 100% Vegetal Monday the consumption of all products of animal origin) by replacing it with products of vegetable origin.
- the Green Monday (promoter: the Municipality of Berkley, California) adds the fight against food waste and the introduction of eco-friendly behaviour to what is already included in Vegetal Monday.
- in Denmark, German and Argentine the government adopted itself the vegan Monday to promote change
- On 1 November each year, the world celebrates World Veganism Day, established in England in 1994 by the Vegan Society.

Accepting the suggestion of this kind of initiative, in this paper, we want to give a spatial comparison between a full Mediterranean diet and a Mediterranean diet, where one, two and three days were substituted with the vegan diet, in order to map and quantify how much it could be the savings in terms of water, greenhouse gas emission and deforestation. The study of the spatial distribution of consumptions can be also useful for policies that could steer population toward a nutrition more plant-based.

4 Materials and Methods

Since the objective in this work is to demonstrate how the introduction of a 100% plant-based diet, not necessarily for all the week, but even just followed 1–2–3 days a week, can contribute to the reduction of environmental impacts in terms of CO_2 and waterprint reduction and to spatialize the distribution of this reduction, first of all the workflow followed is described below.

1. Data from the Italian ISTAT census sections of 2021 were used.
2. The following population groups were identified:
   a. children and adolescents from 0 to 17 years of age. This age group was not taken into account in the analysis, as the variation in diet type and calorie requirements is indeed very variable, depending on the additional age sub-groups, but also on other parameters that are difficult to assess (e.g. presence or absence of breastfeeding, growth rate) even though a well balanced diet is also provided for this age group [23].
   b. Adults from 18 to 64 years of age. For these subjects, calorie consumption can vary between 1200 and 3200kcal per day. We have chosen to make our calculations only for an intermediate values of 2000kcal [18].
   c. Seniors aged 65 and over [32]. Also this sensitive class was excluded by the analysis
3. For the adult group, an ideal daily diet has been considered taking into account scientific studies in the field, both from the point of view of an all-vegetable diet and from the point of view of an omnivorous diet of the Mediterranean Diet type [33]. For the group of adults, an ideal daily diet was chosen taking into account the relevant scientific studies, both from the point of view of a plant-based diet [18] and from the point of view of an omnivorous diet of the Mediterranean Diet type [27]. Therefore,

four dietary patterns were identified: the first completely omnivorous and based on the Mediterranean Diet (Table 1), the second by adding one entirely vegetable day (Table 2), the third by adding two entirely vegetable days (Table 3) and finally the fourth by adding three entirely vegetable days (Table 4) per week.

4. After attributing the food consumption to the different population groups, the greenhouse gas emission (GHGS expressed in $kgCo_2$/kg food as eaten), land use (LU expressed as m^2*year/kg food as eaten) [34, 35] and water footprint (m^3 / t) [36–38] were associated to each food group (Tables 1–2–3–4).
5. Finally, values resumed in Tables 1–2–3–4 were used to associate GHGS, LU and water footprint to the adults present in each Italian Municipality and to obtain the resulting maps (Figs. 1–2–3–4); totals were compared.

Table 1. Dietary pattern of omnivorous diet for one week (adults, 2000kcal) and related production of CO_2, land use consumption and water footprint.

Food groups	Food groups	Number of servings/ total recommended per week	Standard portion (g)	Total serving size per week (g)	GHGE ($kgCo_2$/kg food as eaten)	LU (m^2*year/kg food as eaten)	Water footprint (m^3 / t)
Grains	Bread	24.5	50	1225	3.9	5.8	1644
	Whole cereal grains/ pasta/bulgur/couscous/ready-to-eat cereals	10.5	80	840			
	Grains: potatoes	2	200	400			387
Protein-rich foods	Red meat, white meat	3	100	300	17.1	28.5	15415 5000
	Fish	2	150	300	15.2	2.1	1629
	Canned fish	1	50	50			
	Eggs	3	50	150	5.3	16.1	3265
	Legumes	3	150	150	2.1	7.9	3160
	Milk/yogurt	21	125	2625	11.5	11.5	9000
	Cheeses up to 25% fat	2	100	200			3180
	Cheeses with more than 25% fat	1	50	50			
Fruit and vegetables	fresh fruit	21	150	3150	1.2	1	962
	Fresh vegetables	10.5	200	2100	1.8	0.8	322
	Salads	7	80	560			
Fats and seasoning		21	10	210	7.1	16.9	2364
Nuts		2	30	60	2.1	7.9	9063

5 Results and Discussion

The maps produced show a series of maps of Italy displaying, respectively, greenhouse gas emissions (GHGE) in kg CO2 per week (Fig. 1), land consumption (LU) per week (Fig. 2) and water footprint again per week (Fig. 3). Within each image are shown the

Table 2. Dietary pattern of a combination of omnivorous diet and one day of vegan diet for one week (adults, 2000kcal) and related production of CO_2, land use consumption and water footprint.

Food groups	Food groups	Number of servings/ total recommended per week	Standard portion (g)	Total serving size per week (g)	GHGE ($kgCo_2$/kg food as eaten)	LU (m^2*year/kg food as eaten)	Water footprint (m^3 / t)
Grains	Bread	24.5	50	1225	3.9	5.8	1644
	Whole cereal grains/ pasta/bulgur/ couscous/ready-to-eat cereals	10.5	80	840			
	Grains: potatoes	2	200	400			387
Protein-rich foods	Red meat, white meat	2	100	200	17.1	28.5	15415 5000
	Fish	2	150	300	15.2	2.1	1629
	Canned fish	1	50	50			
	Eggs	3	50	150	5.3	16.1	3265
	Legumes	5	150	750	2.1	7.9	3160
	Soy milk	2	200	400	2.1	7.9	3160
	Milk/yogurt	18	125	2250	11.5	11.5	9000
	Cheeses up to 25% fat	1	100	100			3180
	Cheeses with more than 25% fat	1	50	50			
Fruit and vegetables	fresh fruit	21	150	3150	1.2	1	962
	Fresh vegetables	10.5	200	2100	1.8	0.8	322
	Salads	7	80	560			
Fats and seasoning		21	10	210	7.1	16.9	2364
Nuts		2	30	60	2.1	7.9	9063

indicators mentioned in the case where the population follows a completely Mediterranean diet (top left) and in the case where they introduce one day (top right), two days (bottom left), three days (bottom right) of vegan diet within the week.

The intervals of the created legends highlight the deciles of values found for each indicator and have been stylized with colors ranging from blue, for lower values, to red, for higher values.

What emerges from the maps produced is the progressive reduction of the red areas as the number of vegan days introduced into the diet increases and thus the positive impact on pollution from reduced consumption of animal by-products.

The results, as calculated, are obviously proportional to the number of inhabitants, so that the different environmental impacts assessed are dependent on the population density of each region, but also with respect to the multiplicative coefficient for each specific type of impact. What has been identified from the three maps produced has been summarised by means of superimposed bar diagrams (Fig. 4). From these diagrams it is evident that the highest impacts derive from the regions of Lombardy, Emilia-Romagna and Veneto, while the regions with the lowest impacts are Basilicata, Molise and Valle d'Aosta, due to their low population density, and it is immediately visible how these impacts decrease as we progressively move from a standard Mediterranean diet to an

Table 3. Dietary pattern of a combination of omnivorous diet and two days of vegan diet for one week (adults, 2000kcal) and related production of CO_2, land use consumption and water footprint.

Food groups	Food groups	Number of servings/ total recommended per week	Standard portion (g)	Total serving size per week (g)	GHGE ($kgCo_2$/kg food as eaten)	LU (m^2*year/kg food as eaten)	Water footprint (m^3 / t)
Grains	Bread	24.5	50	1225	3.9	5.8	1644
	Whole cereal grains/ pasta/bulgur/ couscous/ready-to-eat cereals	10.5	80	840			
	Grains: potatoes	2	200	400			387
Protein-rich foods	Red meat, white meat	2	100	200	17.1	28.5	15415 5000
	Fish	1	150	150	15.2	2.1	1629
	Canned fish	1	50	50			
	Eggs	1	50	50	5.3	16.1	3265
	Legumes	8	150	1200	2.1	7.9	3160
	Soy milk	6	200	1200	2.1	7.9	3160
	Milk/yogurt	12	125	1500	11.5	11.5	9000
	Cheeses up to 25% fat	1	100	100			3180
	Cheeses with more than 25% fat	1	50	50			
Fruit and vegetables	fresh fruit	21	150	3150	1.2	1	962
	Fresh vegetables	10.5	200	2100	1.8	0.8	322
	Salads	7	80	560			
Fats and seasoning		21	10	210	7.1	16.9	2364
Nuts		2	30	60	2.1	7.9	9063

increasingly plant-based diet. This downward trend appears to be similar among regions, but with variation in absolute levels from GHGE production to land consumption to water footprint estimation. More specifically, the effects of the vegan diet are more evident on GHGE emissions and less on water footprint.

It is clear that in the work an ideal, purely theoretical situation has been evaluated because it is based on guidelines, while it does not take into account actual consumption, which often involves much higher consumption of animal products than indicated.

- Other factors to be investigated in more fact-based studies should also take the following considerations into account: there are already people in Italy who follow a vegan diet full-time and others who follow it part-time and thus already contribute to the reduction of environmental impact.
- Within the population there are % overweight or obese people who generally consume more than the theoretical diets. However, it should be noted that this fact has not been taken into account for both the 100% Mediterranean diet and diets with the inclusion of vegan days.
- The assessment of the pollution produced by the individual food categories has also been simplified in this work, as both the Mediterranean diet and the introduction of 100% vegetable days are important for the assessment of environmental impacts. In

Table 4. Dietary pattern of a combination of omnivorous diet and three days of vegan diet for one week (adults, 2000kcal) and related production of CO_2, land use consumption and water footprint.

Food groups	Food groups	Number of servings/ total recommended per week	Standard portion (g)	Total serving size per week (g)	GHGE ($kgCo_2$/kg food as eaten)	LU (m^2*year/kg food as eaten)	Water footprint (m^3 / t)
Grains	Bread	24.5	50	1225	3.9	5.8	1644
	Whole cereal grains/ pasta/bulgur/ couscous/ready-to-eat cereals	10.5	80	840			
	Grains: potatoes	2	200	400			387
Protein-rich foods	Red meat, white meat	2	100	200	17.1	28.5	15415 5000
	Fish	1	150	150	15.2	2.1	1629
	Canned fish	1	50	50			
	Eggs	1	50	150	5.3	16.1	3265
	Legumes	8	150	1200	2.1	7.9	3160
	Soy milk	9	200	1800	2.1	7.9	3160
	Milk/yogurt	12	125	1500	11.5	11.5	9000
	Cheeses up to 25% fat	1	100	100			3180
	Cheeses with more than 25% fat	1	50	50			
Fruit and vegetables	fresh fruit	21	150	3150	1.2	1	962
	Fresh vegetables	10.5	200	2100	1.8	0.8	322
	Salads	7	80	560			
Fats and seasoning		21	10	210	7.1	16.9	2364
Nuts		2	30	60	2.1	7.9	9063

fact, the place where the food is produced, the amount of transport it requires, as well as the way in which the food is produced and packaged, be it vegetable or animal, are important. From this point of view, the EU has recently been considering the integration of environmental and nutritional criteria into the food labelling system (Farm to Fork Strategy [39]). Some countries, such as France, have already adopted this system with an Eco-Score in which 16 environmental parameters including land use and water consumption are included on the label.

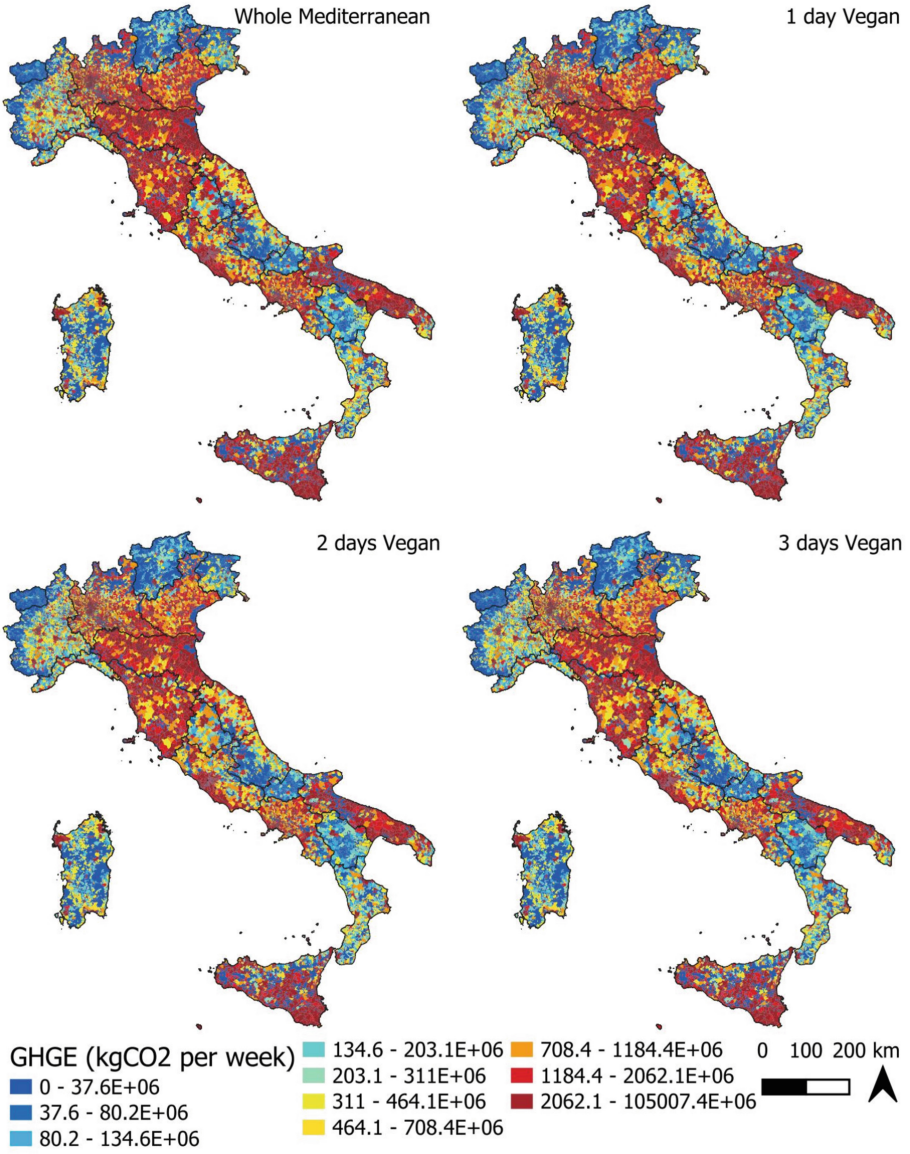


Fig. 1. Map of the distribution of GHGE emissions ($kgCO_2$ per week) in the Italian Municipalities, respectively for the whole Mediterranean diet (top left) and after introducing one day (to right), two days (bottom left), three days (bottom right) of Vegan diet.

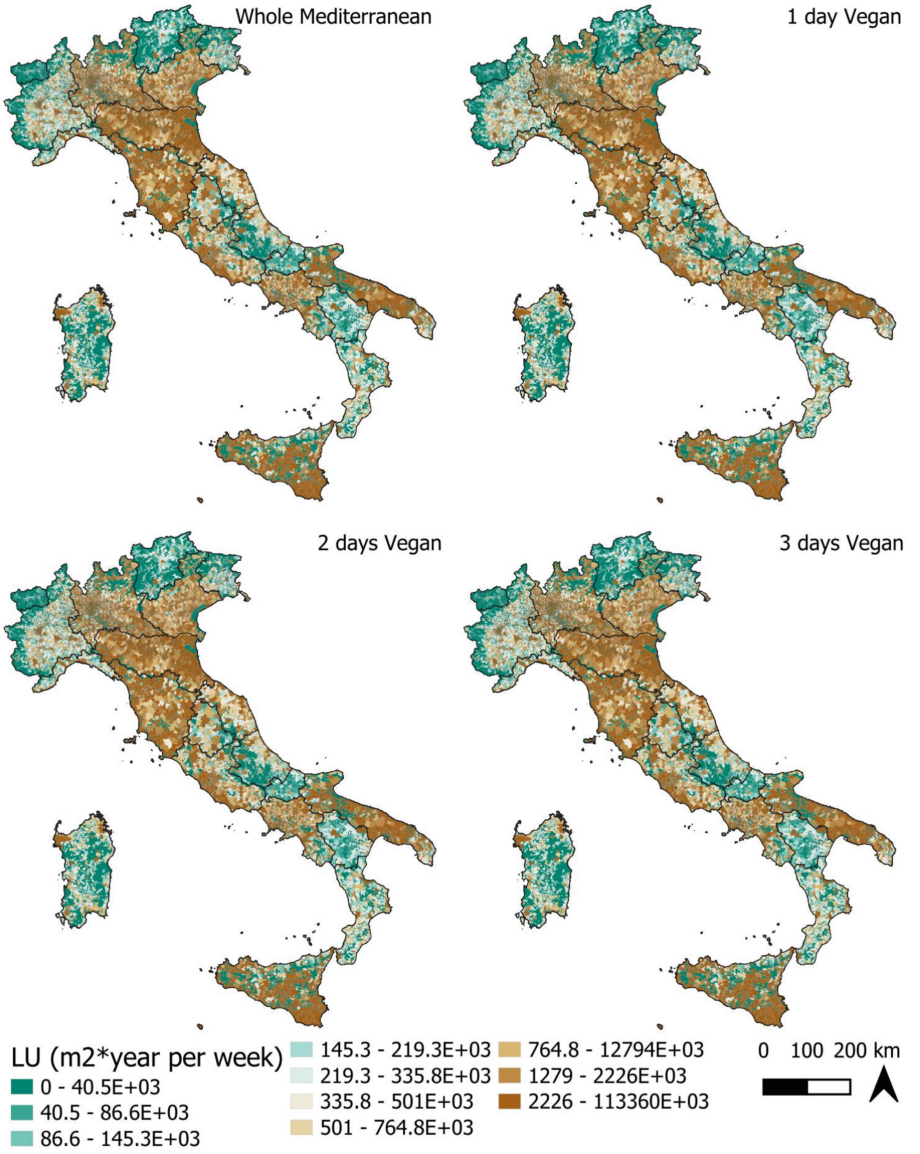


Fig. 2. Map of the distribution of GHGE emissions ($kgCO_2$ per week) in the Italian Municipalities, respectively for the whole Mediterranean diet (top left) and after introducing one day (to right), two days (bottom left), three days (bottom right) of Vegan diet.

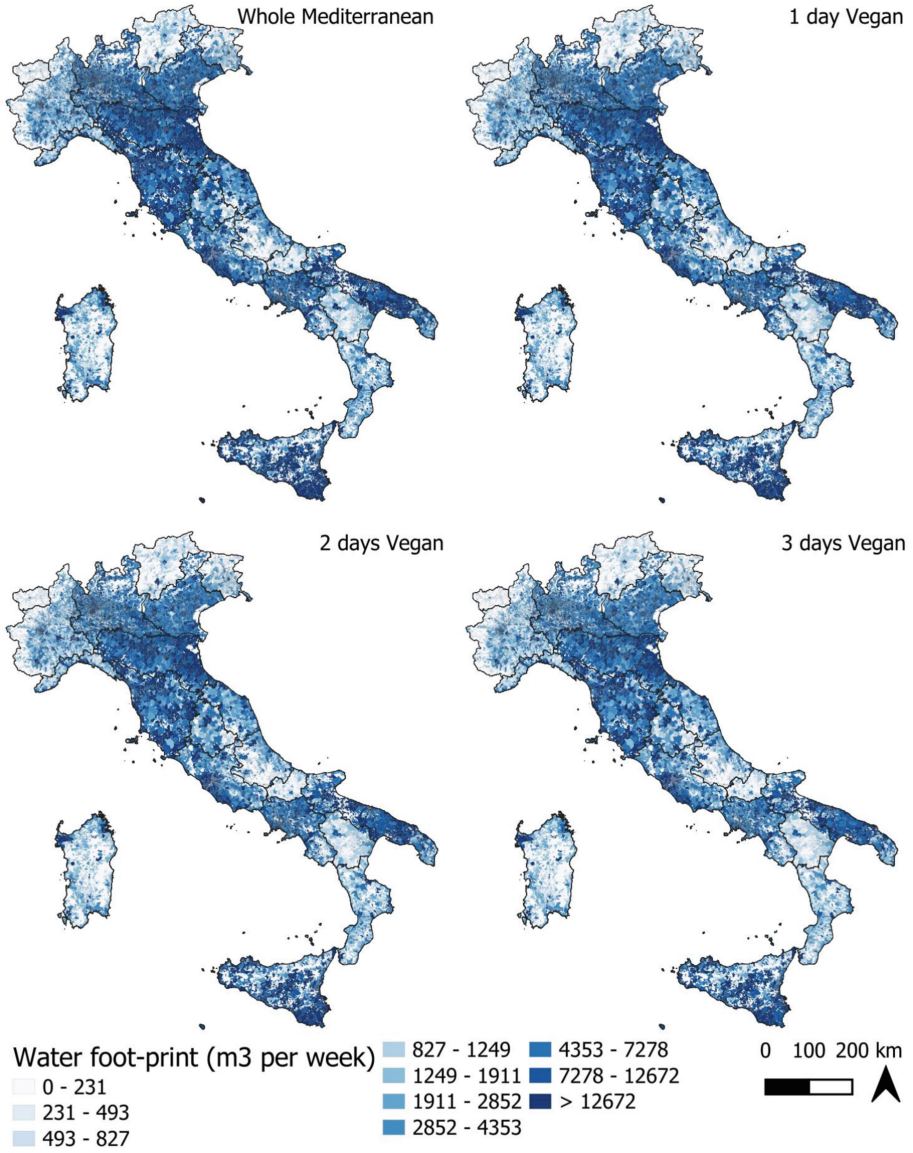


Fig. 3. Map of the distribution of water foot-print (m^3 per week) in the Italian Municipalities, respectively for the whole Mediterranean diet (top left) and after introducing one day (to right), two days (bottom left), three days (bottom right) of Vegan diet.

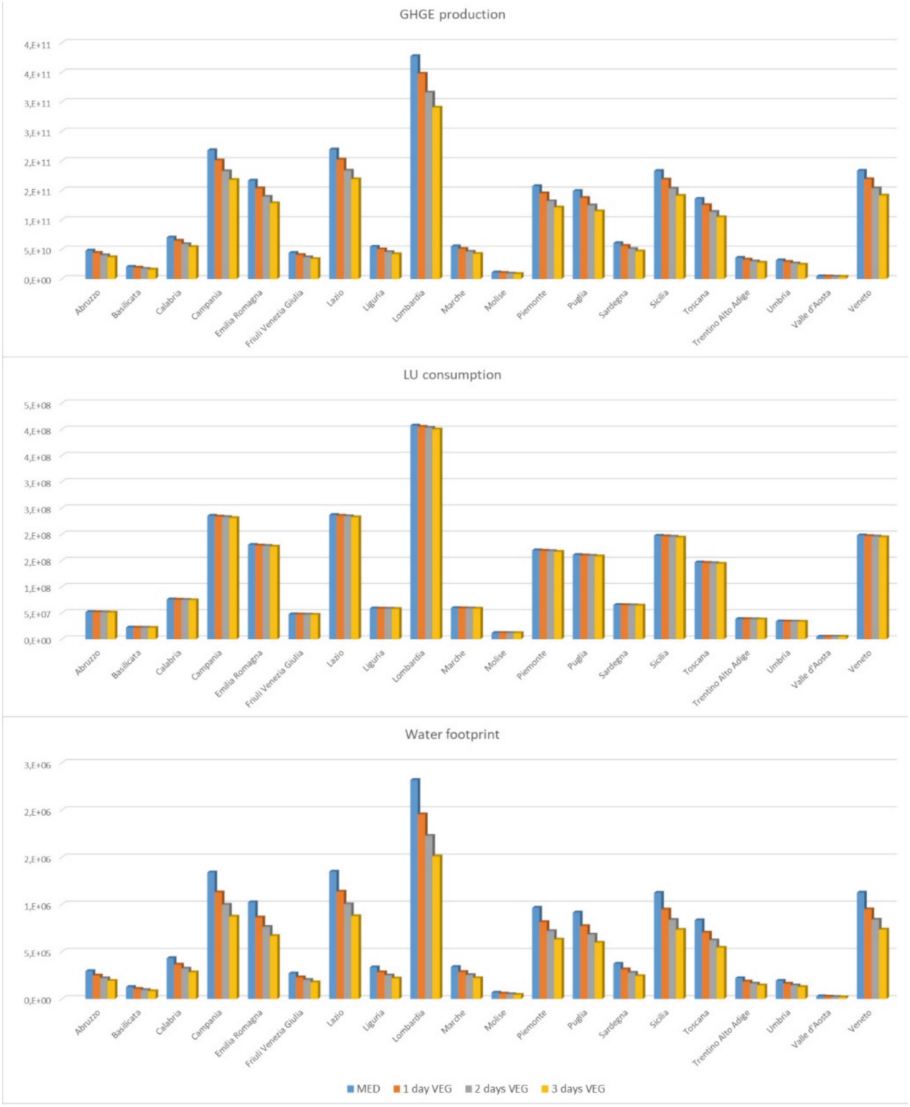


Fig. 4. Environmental impact of diet in different Italian regions, measured in terms of GHGE (top), LU consumption (center) and water footprint (bottom). The different colors represent dietary scenarios with a progressive reduction in the consumption of animal products: MED (standard Mediterranean diet), 1 day VEG, 2 days VEG and 3 days VEG.

6 Conclusion

Adopting even just a few days of a vegan diet per week, leading to a reduction in the consumption of animal products can potentially contribute significantly to reducing diet-related environmental impacts in terms of water consumption, greenhouse gas reduction and land consumption.

The maps produced in this work are useful not only to quantify these impacts, but also as a tool to inform sustainable food policies, helping to understand where to incentivise the inclusion of one or more vegan days, based on the amount of impact produced through initiatives such as Vegan Monday, but also to guide and support sustainable food design and consumer awareness campaigns. The spread of a more plant-based culture is indeed fundamental to learning to appreciate and cook new, less impactful dishes with the hope that they will be introduced more independently and thus lead to a spontaneous increase in sustainability at the table.

Finally, although the study is based on theoretical scenarios and ideal nutrition guidelines, it provides a starting point for future research and insights based on more realistic consumption. By introducing other factors such as current eating habits, regional variations in consumption patterns, the impact of local production and logistics into the analysis, it will be possible to further refine strategies for reducing the environmental impact of the food system.

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