



RESEARCH ARTICLE

Balancing Human and Planetary Health Through Plant-Based Diet

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OPEN ACCESS

PUBLISHED

28 February 2025

CITATION

Lal, R., 2025. Balancing Human and Planetary Health Through Plant-Based Diet. Medical Research Archives, [online] 13(2).

<https://doi.org/10.18103/mra.v13i2.6235>

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DOI

<https://doi.org/10.18103/mra.v13i2.6235>

ISSN

2375-1924

ABSTRACT

Dietary preferences, with strong effects on human health and environmental sustainability including climate change, is an emerging scientific discipline of nutrition ecology. Whereas poor food choices are a serious health issue in low- and middle-income countries, malnutrition (hidden hunger) is also a growing concern in developed economies. A western diet based on red meat may be unhealthy and unsustainable because of its adverse impacts on soil, water, air, biodiversity, and human health. Traditional animal-based diets (ABDs) may have aggravated public-health crisis, accelerated anthropogenic climate change, increased vulnerability to pandemics, and accentuated social/psychological anxieties. In comparison, plant-based diets (PBDs) have low health risks, reduced emission of greenhouse gases (GHGs), and less consumption of water and other natural resources. Adoption of PBDs may benefit people and spare some land and water for nature. In addition to lower health risks (i.e., some cancers, obesity, cardiovascular diseases), PBDs also have life-enhancing potential. Recent increasing focus on PBDs may also be due to ethical concerns about animal welfare and environmental friendliness. However, there are several barriers and challenges to adoption of PBDs. Strict vegan diet may aggravate malnutrition among children, nursing mothers, and elderly population. Rather than a radical transition, a holistic approach to PBDs may be an appropriate strategy. A holistic strategy would include using animal products judiciously, balancing human and planetary health through PBDs, and sparing land/water for nature. In contrast with ABDs, balanced PBDs can improve human health and have a positive environmental impact.

Introduction

An unhealthy diet is among major causes of vulnerability to non-communicable diseases (i.e., obesity, diabetes, hyper-tension, some cancers, malnutrition), and growing risks of civil unrest and political instability.¹ The adverse effects of predominantly animal-based diets (ABDs) on planetary processes include anthropogenic global warming, water scarcity, loss of biodiversity etc. Therefore, a trend of shifting from ABDs to plant-based diets (PBDs) is gaining momentum in the interest of enhancing human wellbeing and restoring nature/planetary processes. Interest in PBDs is also growing because of the challenges of ecological sustainability,

human health, animal welfare, and strong inter-connectivity among these issues.² Indeed, transitioning to PBDs may be an appropriate strategy to addressing global issues of the 21st century, putting Sustainable Development Goals (SDGs) of the United Nations Agenda 2030 on track, and reducing the environmental footprint (EFP) of humanity. Examples outlined in Table 1 show notable reduction in EFP through adoption of PBDs. However, without proper planning, requirements of micronutrients for good human health may not be met by PBDs. Thus, there is a strong need to understanding of barriers to a widespread adoption or shift to PBDs.

Table 1. Examples of reduction in environmental footprint by adoption of plant-based diets

Approach	Impact	References
Life Cycle Analysis (LCA)	Moving from omnivorous to vegetarian diet reduced environmental impact	Coelho et al., 2016 ³
Cohort & randomized control trials	Adoption of PBD reduced EFP	Viroli et al., 2023 ⁴
One-Health	Meat products contributed most to EFP	Paris et al., 2024 ⁵
Cardiovascular Health	PBD is environmentally sustainable dietary option	Satija and Hu, 2018 ⁶
Plant-based meat (PBM)	Use of PBM have low EFP	Van Vliet et al., 2020 ⁷
Diet Quality	Low-meat diets are environmentally friendly	Hagmann et al., 2019 ⁸

The objective of this article is to deliberate merits and challenges to adoption of PBDs as a strategy to improve human health while advancing nature conservancy and sustaining planetary processes. The article addresses barriers or challenges to achieving the transition including cultural, social, economic, and political factors which affect acceptability and affordability of PBDs. The article also considers some innovative options such as use of pulses, algal products, and meditation while transitioning to PBDs.

Types of Human Diet

There are four pillars of PBDs (Figure 1), and these must be carefully considered while making choice of specific dietary preferences. Different types of human diet include the following:

THE VEGAN DIET (VGD): It is a vegetarian diet that excludes meat, fish, dairy, honey, and eggs. With proper planning, VGD can have positive effects on obesity, hypertension, and cardiovascular diseases (CVDs).

VEGETARIAN DIET (VDD): It is a vegan diet plus use of dairy products (i.e., milk, cheese, yogurt, ghee).

PESCATARIAN DIET (PSD): It includes VGD plus fish and seafood, but no meat or poultry.

FLEXITARIAN DIET (FXD): It is semi-vegetarian diet that focuses on plant-based food while occasionally including meat. It is a combination of flexible and vegetarian diets.

TERRITORIAL DIVERSIFIED DIET (TDD): It is a flexitarian style diet that includes plant-based food along with seasonal and locally sourced food. Some examples of TDD are Mediterranean and New Nordic Diet.

MEDITERRANEAN DIET (MTD): It involves eating whole unprocessed foods including fruits, vegetables, whole grains, nuts, seeds, and olive oil.

NEW NORDIC DIET (NND): It includes locally sourced sustainable and traditional foods including whole grains, fruits and vegetables, tubers (beets, turnip), fish, and rapeseed oil.

TRADITIONAL WESTERN OR AMERICAN STANDARD DIET (TAD): It is high in saturated and trans fats, refined grains, red meat, processed meat, high sugar drinks and high-fat dairy products. TAD is low in plant-based food, and has high calories, excess sugar and sodium content.

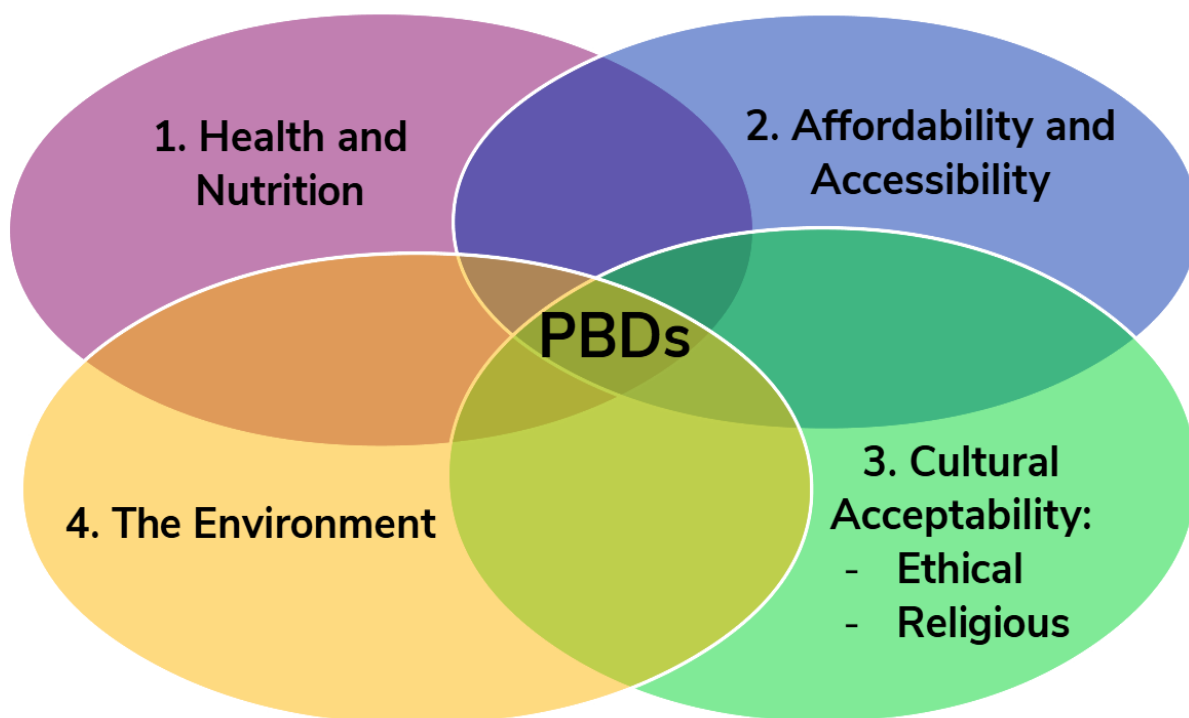


Figure 1. Four pillars of PBDs as outlined by Moreno et al. (2022).⁹ Without professional supervision, use of PBDs (vegan, vegetarian, and pescetarian) can increase the risks of malnutrition among vulnerable population (e.g., infants, children, women, nursing mothers, and the elderly).¹⁰

Plant Based Diets With Meditation and Supplements

There is a wide range of PBDs which exclude or reduce intake of animal products. These PBDs have evolved over millennia and are adapted to specific social, cultural, and ecological environments. PBDs are often used in combination with meditation and some supplements to minimize risks of the deficiency

of micronutrients and other essential ingredients. For example, VDD is often combined with meditation for treatment of some psychological, CVDs, and digestive diseases.¹¹ Potential benefits of PBDs are outlined in Figure 2 and briefly discussed below.

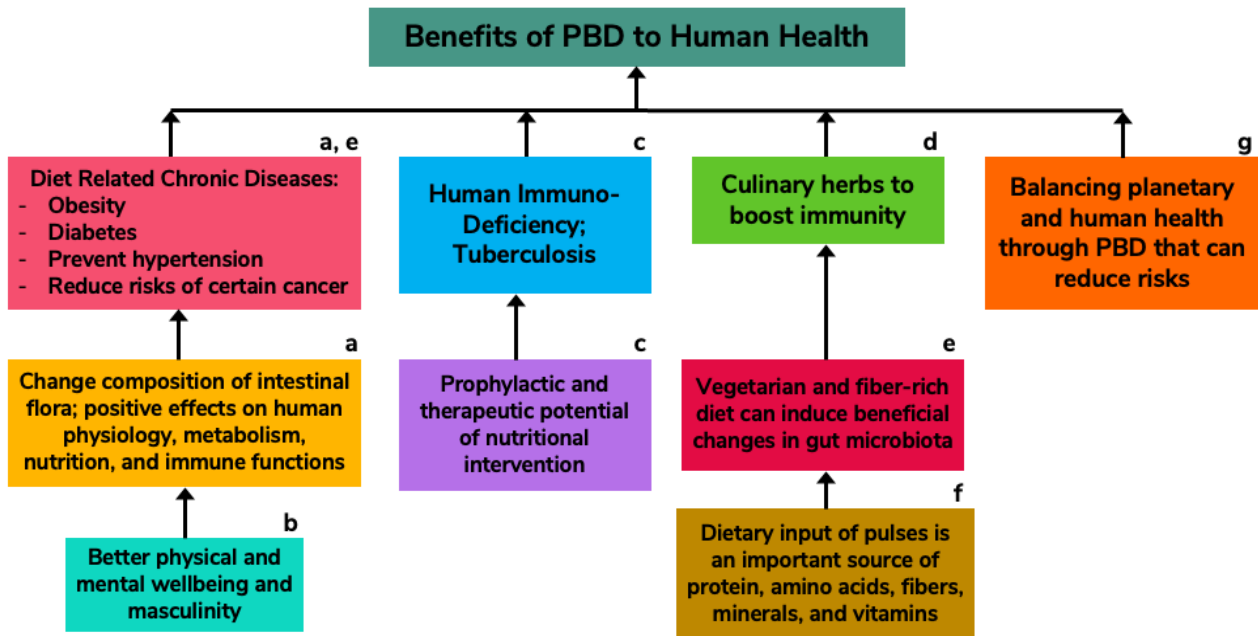


Figure 2. Human-health benefits of plant-based diets: a,¹¹ b,² c,¹² d,¹³ e,¹⁴ f,¹⁵ g.⁹

Reduction in Greenhouse Gas Emissions by Adoption of PBDs

One of the ecological benefits of adopting PBDs is the potential of reducing emission of greenhouse gases (GHGs) from predominantly animal-based foods. While more context-specific research may be needed to check the carbon-footprint (CFP) of PBDs, the data from some examples listed in Table 2 are a cause of optimism. Several approaches,

including the life cycle assessment (LCA) indicate reduction in CFP by decrease in emission of methane (CH₄) and of nitrous oxide (N₂O) through adoption of PBDs. These GHGs have much higher global warming potential (GWP) compared with that of carbon dioxide (CO₂). Transition to PBDs may also reduce the energy and water footprint (ecological footprint or EFP) and enhance terrestrial biodiversity.

Table 2. Reduction of greenhouse gas emission by adoption of plant-based diet

Approach	Impact	References
Individual Carbon Footprint (CFP)	Adoption of PBDs can reduce CFP by 20% and decrease GHG emissions	Rancilio et al., 2022 ¹⁶
Anthropogenic GHG Emissions	Reducing meat consumption can decrease GHG emission in Sweden	Martin and Brando, 2017 ¹⁷
Dietary Shift	Reducing meat may decrease GHG emissions and reduce loss of biodiversity	Stoll-Kleemann and Schmidt, 2017 ¹⁸
Resource Management	Shift to PBD is necessary to mitigating anthropogenic climate change	Mayes, 2017 ¹⁹
Food-Energy-Water (FEW) Nexus	Balanced diet habits can save water, energy, and natural resources	Kheirinejad et al., 2024 ²⁰
Life Cycle Assessment of Diets	Sustainable diets are important to mitigating anthropogenic climate change	Mazac et al., 2023 ²¹

One-Health Benefit of PBDs

The One-Health model states that the health of soil, plants, animals, people, ecosystems and planetary processes is strongly inter-connected. The One-Health model is gaining momentum among agronomists, veterinarians, human nutritionists, and those concerned with planetary health. The data in Table 3 outlines examples of the PBDs which also support the One-Health model as confirmed through diverse approaches including LCA, cohort and randomized control trials of diverse and well-planned

diets. The benefits of PBDs to human health can be enhanced by diversification of diet from traditional crops or forgotten crops of the specific region²². Nutrient dense traditional crops include cereals (sorghum, millet, teff), pulses (chickpeas, mung beans, pigeon peas, lentils), root crops (cassava, yam, sweet potato, taro) and some supplements such as algal products.²³ These traditional crops are dense in essential plant nutrients and other health-positive ingredients. Indeed, well planned PBDs can lead to multiple benefits to human and nature.²⁴

Table 3. One-Health Benefits of PBDs

Approach	Beneficial Impact	References
Life Cycle Analysis	Animal welfare and human health indicators must be included in LCA	Paris et al., 2022 ²⁵
Veganism	Address simultaneously issues of food, health, climate change, and animal justice with better physical and mental health, and healthier masculinities in men	Aavik and Velgan, 2021 ²
Vegetarian diets	Can effectively prevent hypertension, metabolic diseases such as diabetes and obesity, and certain cancers. Long-term vegan meditation can improve body's immunity and adjusting endocrine and metabolic levels, and good health	Jia et al., 2020 ¹¹
Cohort and randomized control trials	PBD diets have beneficial impacts on obesity control, cardiovascular health, and diabetes prevention	Viroli et al., 2023 ⁴
Traditional crops	Chickpea and other traditional crops (pulses) lead to better nutrition and health	Bar-El Dadon et al., 2017 ²²
Algal supplementation	Long chain n-3 polyunsaturated fatty acid deficiencies in vegetarian population can be addressed by using algal supplements	Craddock et al., 2017 ²³
Well-planned vegetarian diet	A holistic approach leading to a wide range of plant foods along with a consistent source of vitamin B12, can provide adequate nutrition	Agnoli et al., 2017 ²⁴

Some Nutritional Constraints of PBDs

Despite numerous benefits of transitioning to PBDs, there are some concerns regarding the risks of micronutrient deficiencies and the attendant human health issues of PBDs which are neither properly planned nor adequately balanced. Important among these concerns (Table 4) are food allergy, low digestibility, existence of some anti-nutritional

compounds, risks of kidney disease in some leafy vegetables which may contain substances which aggravate formation of kidney stones, and toxicity of some substances such as Mn concentration in acai (Table 4). Education about these issues, judicious planning of PBDs, increasing diversity of sources of PBDs including the use of traditional crops, and consultation with specialists in human nutrition can be advantageous to human wellbeing.

Table 4. Health risks of PBDs and environmentally sustainable foods

Causes of Malnutrition in PBDs	References
Lack of essential macro- and micro- nutrients; nutrient deficiencies and risks of non-communicable diseases, deficiency of Fe and Zn	Kalmpourtzidou and Scazzina, 2022 ²⁶ ; Metoudi et al., 2024 ²⁷
Food allergy with PBD	Protudjer et al., 2024 ¹⁰
Low digestibility coefficient for protein and deficiency of amino acids	Adolph, 1954 ²⁸
Existence of anti-nutrient compounds like phytic acid and polyphenols which reduce the mineral bioavailability because of their chelating properties such as in Pearl Millet	Singhal et al., 2022 ²⁹
Risks of high protein intake in some PBD (e.g., pulses) may accelerate underlying kidney disease process	Bernstein et al., 2007 ³⁰
A daily consumption of 300 ml açai (<i>Euterpe oleracea</i> Mart.) may lead to daily intake of Mn (14.6mg) which exceed the recommended dose at 11mg, and it leads to impaired Fe absorption and anemia in children	Santos et al., 2014 ³¹

Planetary Benefits of PBDs

Over and above the benefits to human health and wellbeing, there are also distinct planetary benefits of transitioning to PBDs. Planetary health can be improved by using PBDs which have low CFP, including diverse sources of food (traditional crops of the region along with some pulses), and addressing the problem of malnutrition because of the deficiency

of some micronutrients (e.g., Zn, Fe) in PBDs (Table 5). Examples of specific benefits to planetary.

Table 5. Planetary benefits of PBD

Approach	Impact	References
Carbon Foot- Print	Diets that exhibit low CFPs (e.g., vegan, climatarian, Mediterranean) have a positive effect on human health	Dixon et al., 2023 ³²
Planning	Well-planned PBD is achievable and sustainable in a community setting and has health benefits	Sadler et al., 2024 ³³
Dietary Patterns	There is a strong link between dietary patterns (e.g., vegetarian diet) and improved health	Orlich and Fraser, 2014 ³⁴
Addressing Malnutrition	PBDs (along with use of pulses and traditional crops) can achieve a malnutrition-free world while providing significantly higher intake of ascorbate, folate, magnesium, copper, and manganese	Kumar et al., 2023 ¹⁵

processes are reducing CFP, decreasing emission of GHGs, increasing above and below-ground biodiversity, sparing land and water, and reducing risks of degradation of soil (i.e., erosion, elemental imbalance, loss of soil organic matter content, decline in soil structure), eutrophication of water, and pollution of air.

General Considerations

An objective assessment of PBDs for human and planetary health need careful assessment of the following:

1. HEALTH IMPACTS OF PLANT-BASED DIETS

PBDs are receiving a lot of attention and more visibility because of their potential for health benefits, and possibility of positive environmental impacts. PBDs contain some ingredients which may have some independent health benefits^{35,36,37}. Several studies have indicated that PBDs can reduce risks of developing diabetes, hypertension, CVDs, dementia and some cancer^{38,39,40,41}. Vegetarian diets are also associated with reduction in weight, blood pressure, glycosylated hemoglobin for low-density lipoprotein cholesterol⁴¹. Beneficial impacts of PBDs are due to

low intakes of saturated fats and high intakes of dietary fibers. However, potentially deleterious effects of PBDs are due to lack of some micronutrients, vitamin D, and B12, Ca, Fe, Zn and I⁴². PBDs lead to smaller risk reduction in CVDs, diabetes mellitus, and chronic kidney disease⁴³. Yet, there are limited data for cancer and CVDs. PBDs may also adversely affect bone-mineral density and risks of lumbar fracture and bone health⁴⁴.

Effects of PBDs on quality of life (physical, psychological, social, and environmental) are not widely studied. The choice of adopting PBDs may have positive impacts such as improved physical health, positive feelings related to morally-correct attitude, an increased sense of belonging to a wider community, and lower EFP⁴⁰. But there may also be some negative impacts of adopting PBDs on quality of life such as environment, social/cultural group, gender-based differences, economic status, and a limited access to PBDs⁴⁰.

Adoption of PBDs may also lead to higher levels of pesticides in consumers suggesting that consumption of organic produce may reduce exposure to

organophosphate pesticide residues in vegetarians⁴⁵. In comparison with ABDs, vegetarians are known to have a lower mean body mass index or BMI (in kg/m²), a lower mean plasma total concentration (in 0.5mmol/l), and a lower mortality from coronary artery disease (~25%)⁴⁶. Those following PBDs may also have lower risks of some other diseases, gallstones and appendicitis⁴⁶. However, there may be no differences in mortality from common cancers. There is a lack of information about an association between PBDs and cancer prevention³⁷.

2. ENVIRONMENTAL IMPACTS OF PLANT-BASED DIETS

In general, PBDs are less resource-intensive and have lower EFP than those of ABDs^{47,48,49,50}. In other words, PBDs are more environmentally sustainable than are ABDs. Thus, adopting PBDs high in fiber may reduce global warming and prevalence of obesity and other diseases⁵¹. However, long-distance air transport, deep freezing, and some horticultural practices may increase EFP of PBDs⁴⁷.

GHG emissions from PBDs may be 35 to 50% lower than that for ABDs with attendant impacts on the use of natural resources^{52,53}. The GWP impacts of ABDs can be substantially more than those of PBDs, and environmental indicators show a positive

association with the amount of PBDs consumed^{49,54,55,56,57}. Emission of GHGs may be reduced by more than two-fold for PBDs (0.9kg) compared with that of ABDs (2.1 kg CO₂ equivalent per meal)⁵⁸. Thus, changing from ABDs to PBDs may reduce the EFP due to climate change, eco-toxicity, acidification and eutrophication⁴⁹. Food waste may also be lower in PBDs than with ABDs⁵⁶.

3. CHALLENGES TO PROMOTING PBDs IN DEVELOPED ECONOMIES

Interdisciplinary scientific discipline of nutrition ecology⁵⁹ is pertinent to addressing the global issues of human and planetary health. Despite substantial benefits, both in terms of health and environmental impacts, ABDs may be more attractive to consumers than PBDs⁶⁰. The more restrictive the PBD and younger the child, the greater the risks of nutritional deficiency of protein quantity and quality, Fe, Zn, Se, Ca, riboflavin, vitamins A, D, B12 and essential fatty acids⁶¹. Thus, an adequate planning is critical to reducing health-related risks of PBDs. Well-planned PBDs must include numerous protective fibers (i.e. fiber, phytochemicals) and carefully chosen diverse sources including pulses and nuts. The choice of personal vs. planetary health is also a moral and ethical issue⁶².

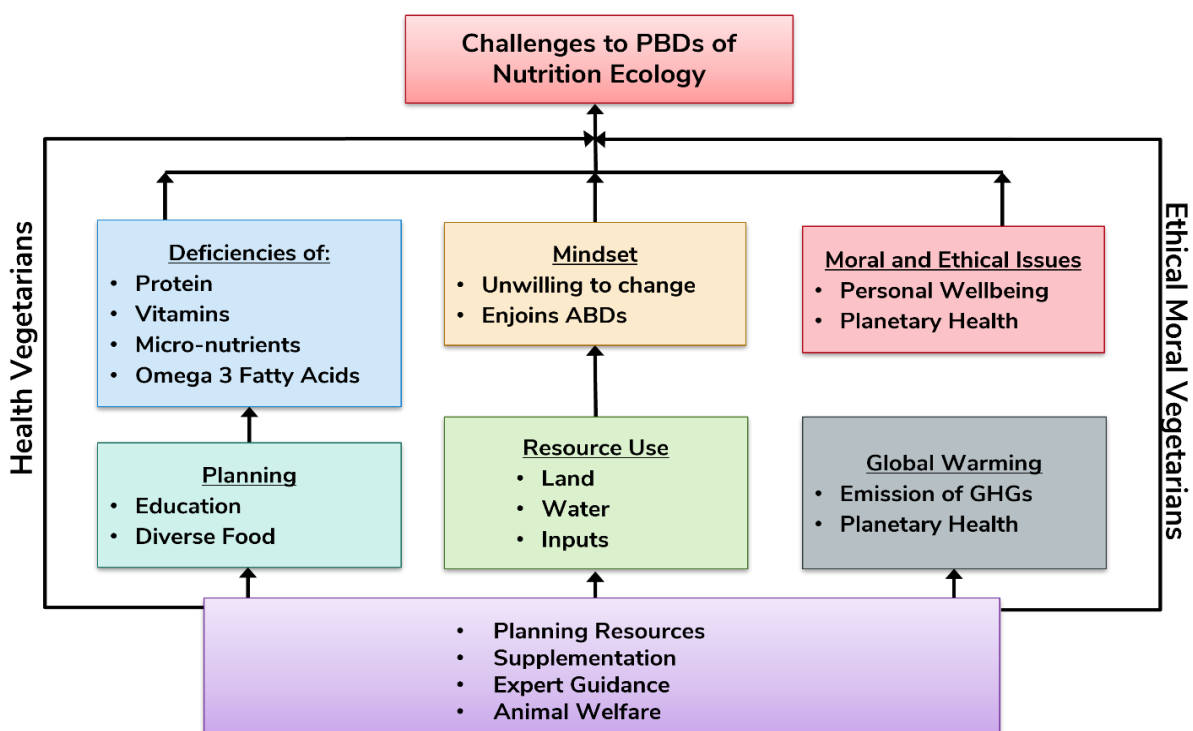


Figure 3: Challenges to adoption of plant-based diets

Primary barriers to adopting PBDs include the mindset about enjoying eating ABDs and unwilling to change the eating habits⁶³. In addition, PBDs also have health risks of deficiencies of protein, omega-3 fatty acids, vitamin D, vitamin B12, Fe, Ca, and Zn⁴³. Restrictive and unbalanced PBDs may lead to nutritional deficiencies, especially in situations of high metabolic demand⁶⁴. A complete PBD in a young child would need substantial commitment, expert guidance, planning, resources, and supplementation^{61,65}. Similar precautions are needed for pregnant women⁶⁶. There is also a question of “health vegetarian” versus “ethical vegetarian”.⁶⁷ The former is motivated by the perceived threat of disease and the latter by animal welfare and planetary health. These issues must be critically considered (Figure 3).

Conclusions

The humanity is at a critical crossroads of growing and increasingly affluent population, anthropogenic global warming, and wide-spread problems of under nutrition and malnutrition. These problems are being aggravated by natural and political causes which have led to disruptions in food production and supply chains, as well as decreased the amount and quality of food produced from agro-ecosystems. Thus, the choice of diet must be made in view of its impact on resources needed to produce food (soil, water, inputs, energy), EFP, and risks of non-communicable diseases (e.g., obesity, diabetes, some cancers) which are being aggravated by excessive reliance and indiscriminate use of ABDs. Choice of diet is also a moral question of personal or planetary benefits. Because there are several types of PBDs, an adequate planning is needed with regards to: a) **diversity of food** sources (traditional crops, pulses, and some algal based supplements), b) **advice of specialists** in human nutrition, c) **guidance from scientists** in management of natural resources (i.e., soil scientists, hydrologists, plant scientists), d) **education of mothers** and planners about the strategies of reducing risks of malnutrition caused by deficiency of micronutrients (Zn, Fe) in PBDs, and e) **interaction with policy**

makers to promote adoption of PBDs. The risks of deficiency of micronutrients with some PBDs are aggravated by low digestibility and low density of some critical nutrients in predominantly cereal-based diets (rice, wheat). Thus, a judicious choice of appropriate PBDs, in combination with diverse sources which include traditional crops and pulses and some supplements, can enhance health of human and address some critical planetary processes through sparing of some land and water for nature.

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