



Nature-based agriculture for an adequate human microbiome

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Abstract In the discussion about food and the environment, most focus is on climate and nutrients. Food in relation to human health is an issue that gets much less attention. But what is healthy food and how can we couple food, health, and the environment more strongly to reach a more integral approach from a system perspective? Here I will discuss the potential of a nature-based food system in relation to health and wellbeing. It is hypothesized that for a healthy diet, both nutritious food and nature-based foods are essential. Nature-based foods contribute to maintaining a healthy human microbiome and are therefore an essential part of diets containing landless and ultra-processed foods. Furthermore, maintaining the essential microbiology has consequences for how and where we produce our foods. Therefore, a conceptual framework is proposed for nature-based food production.

Keywords Nature-based agriculture · Food · Diet · Microbiome · Conceptual framework

Introduction

With the growing population and the increased wealth in large parts of the world, there is an ongoing concern about food security, as the increase in the agricultural

land is limited (e.g., FAO 2012). In history, mankind has been worried about our ability to produce enough food for the growing population. We refer often to Malthus' "Essay on the Principle of Population, as it affects the Future Improvement of Society", published in 1798 and to Sir William Crookes, who in his Presidential Address to the British Association for the Advancement of Science in 1898 appealed to the chemists: "The fixation of atmospheric nitrogen is one of the great discoveries, awaiting the genius of chemists." The invention of chemical nitrogen fertilizer has without doubt contributed to increased world food production by resolving the limitation of N in agricultural systems. After a period of intensive research, the Haber-Bosch process was fit to chemically produce ammonia on an industrial scale and this formed the basis of fertilizer production. The chemical N-fixation and the industrial Haber-Bosch process for ammonia production is now one of the most efficient and most used processes in the chemical industry and thereby one of the most important inventions in mankind (Smil 2001; Erisman et al. 2008).

Nowadays, again there is a strong appeal to scientists to increase food production to feed our growing population (more than 9.8 billion in 2050, UN 2017) and to improve the nutrition of almost one billion, that are undernourished (FAO 2018). This time, however, the call is not addressed to chemists to solve the nitrogen issue, but much broader, to natural and social scientists in general. Intensification of agricultural land to close the so-called yield gap is seen as the basis for ending hunger, the second Sustainable Development Goal of the UN (SDG 2016). Many reports and papers address

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the issue of global food security, the closing of the yield gaps, diets, and food waste (Bruulsema et al. 2009; Tilman et al. 2011; Godfray et al. 2010; FAO, Foley et al. 2011; Mueller et al. 2012). Others warn caution against the environmental and climate consequences of intensification of agriculture (e.g., Balmford et al. 2018; Willett et al. 2019). There is also a growing awareness of the relation between food/diet, lifestyle, and diseases, such as obesity, cardio-vascular disease, etc. It is estimated that in the top 10 of death causes food related diseases make up a large part (WHO 2018a).

The question is, if food quality is relevant in relation to food security, lifestyle, and food safety to merit more attention. This paper discusses the knowledge about food quality in relation to human health and the value of nature-based agricultural solutions. The paper starts with an overview of the trends in food quality, followed by a literature overview of potential explanations of changes in food quality. Then the microbiology of food and health is discussed in relation to land-based and landless food and finally nature-based solutions are proposed to support the microbiological aspects of food and health.

Changes in food quality

There has been relatively little attention to the effect of fertilization on food quality. The nutrient content of food crops has decreased during the past decades in the USA (Davis et al. 2004), UK (Mayer 1997) and Switzerland (Pharmaceutical company Geigy 1985 (Switzerland); Food Laboratory Karlsruhe/ Sanatorium Oberthal) (Fig. 1). Climate change and the elevated levels of CO₂ in the atmosphere might have contributed to these changes (Dietterich et al. 2015; Myers et al. 2014). However, there are different other hypothesis. Davis (2009) introduced the dilution effect, being the increases in yield and decreases in nutrient content. There could be an effect of fertilization on nutrient contents of crops. However, there could also be an effect of crop breeding focused on growth rather than quality of crops.

Food quality is basically a healthy diet as advised by WHO (WHO 2018b). Food quality is defined here, as the components humans need to be healthy and resilient. Plants are biochemically complex organisms, capable of synthesizing a nearly full complement of essential dietary micronutrients (the exceptions being vitamins D and B12). These include the well-known components,

such as macro and micronutrients (essential fatty acids, oils, vitamins, amino acids, antioxidants, fibers, minerals, trace elements). Furthermore, there is a range of components in food where we suspect that they have a function, but we do not know which. Research so far focused on the function of individual components in relation to health or healing properties. The interaction between the components is unstudied and therefore unknown. Furthermore, there is an open research area about the relation between the microbiome in different natural and human systems and its effects on health.

Land-based or landless food?

Diets play an important role in food security and ecological aspects (Foley et al. 2011; Willett et al. 2019). A balanced diet rich in fruit and vegetables, regardless of how these are produced, has been recommended (Magkos et al. 2003; WHO 2018b). However, here it is argued that from a health aspect, this recommendation is incomplete. Recently a lot of research has been focused on the human microbiome and the relation to diseases. The new DNA sequencing techniques made it possible to study the microbiome of the human gut, plants, soils, etc. A range of diseases are related to distortion of the human microbiome (e.g., Blum 2017). The human microbiome is closely related to the plant and soil microbiome, and it is hypothesized that the consumption of fresh land-based (nature-based) food contributes to an adequate human microbiome. If so, a diet composed of ultra-processed and/or landless produced food should at least be accompanied by a share of fresh food to maintain and support good health. Through the ultra-processing of food, the micro-biology is changed and its functionality reduced and certain landless foods such as algae or weeds contains a different microbiome than that of nature-based food. Therefore, land-based food is essential in a diet to maintain the microbiological cycle and therewith the resilience of humans through a healthy microbiome. Research is needed to demonstrate what the share of nature-based food should be to maintain the human microbiome and whether this should be of local and regional origin. Furthermore, research should be done on the effect of using chemicals in agriculture affecting the microbiology in soils and plants and therewith the human microbiome (Tsiafouli et al. 2015; Blum et al. 2019).

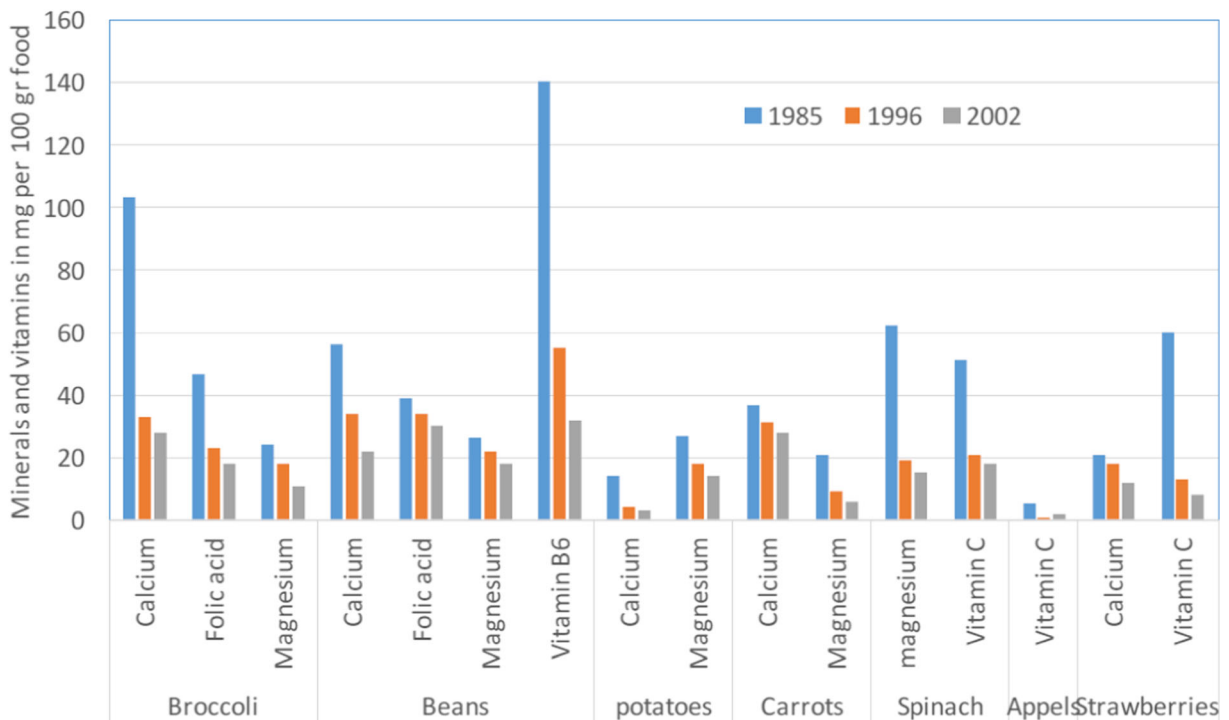


Fig. 1 Minerals and vitamins measured in three different years in mg per 100 g food. Source: Pharmaceutical company Geigy 1985 (Switzerland); Food Laboratory Karlsruhe/ Sanatorium Oberthal

The consequence is that land-based food should be focused on the production of crops, dairy products, and meat focused on safe nutritious food but also with an adequate microbiology. For this, new approaches are probably necessary, because it requires a whole new research area, focused on a new component of food. However, one might reason that biodiversity and food produced with limited amount of chemicals is essential. For this, we developed the nature based food production, which is good for biodiversity, diverse food, microbiology, and limiting environmental impacts.

Nature-based food production

Nature-based agriculture is a form of sustainable agriculture and part of a resilient ecosystem and food system. It makes optimal use of ecological processes and integrates them into farming practice. Nature-based agriculture also directly contributes to the quality of the natural environment itself, producing food within the boundaries set by the environment and having a positive impact on biodiversity. There are various connections and interactions between these dimensions. They refer

to the four interconnected elements described in the conceptual framework for biodiversity in sustainable dairy farming (Erisman et al. 2016, Fig. 2):

1. Functional agro-biodiversity (aimed primarily at soil quality, mineral cycles and plants).
2. Landscape diversity (in particular landscape elements on the farm itself, of benefit to functional agro-biodiversity).
3. Source areas and wildlife corridors (in particular, measures at landscape scale, coordination between Nature Network Netherlands, management, exchanges between areas, etc.).
4. Specific species (additional measures for species conservation and support). This level is, apart from the first three, not connected to agricultural production rather than societal demands to restore and maintain specific species.

Nature-based agriculture using and supporting the microbiology requires a link between functional agro-biodiversity and natural values, such as landscape and specific target species. The soil landscape and

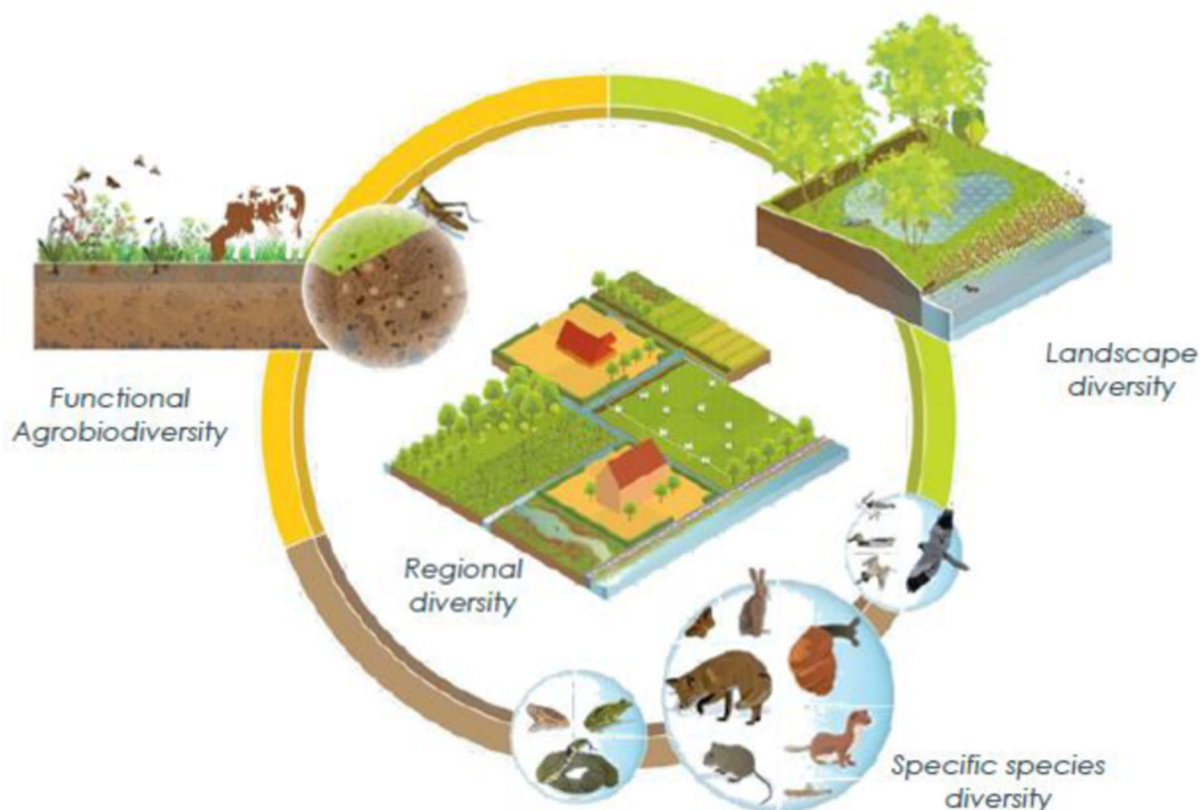


Fig. 2 Conceptual framework for sustainable dairy farming (Erisman et al. 2016)

hydrology determine the type of agriculture that fits best in terms of using the natural microbiology and ecology of the system. Healthy soil, which can hold and deliver water and nutrients, sequester carbon, and maintain soil life, is essential (Pilar 1 Fig. 2). The role of healthy soil in agriculture is supported by landscape elements which have a dual function: they form the basis for functional agro-biodiversity, like pollination and pest control, and support specific target species. These are species (such as farmland birds and meadow birds) which represent the natural quality of the agricultural landscape and are dependent on specific habitats (Pilar 2 Fig. 2). Nature and landscape quality can be further enhanced through proper coordination within a region (Pilar 3 Fig. 2). The foundation is thus laid for both a productive agriculture and for target species. However, additional measures, including postponed mowing dates for grass at the expense of production on the farm, are also needed in order to protect and support those species (Pilar 4 Fig. 2).

Conceptual framework in practice

Nature-based agriculture has in the Netherlands contributed to financially resilient farms in practice: they are low-risk because of the low financial burden because of the limited inputs and are more resilient at all levels (ecological and also economic), according to an initial assessment (Erisman et al. 2016; Erisman and Verhoeven 2019). While the biodiversity is high and environmental burden of these farms is low, the microbiology has not been assessed and therefore it is unknown of the food from these farms can contribute to an adequate human microbiome. More research is needed to assess the relations between farm management and its microbiology. Furthermore, more research is also needed to determine how the conceptual framework for nature-based agriculture can help restore deteriorated agricultural systems and/or build up productive agricultural systems in areas where there is a shortage of food and production levels are low.

It is relevant that nature-based farms in the Netherlands have a long-term vision. The conceptual framework is now applied in the dairy sector by the major dairy cooperation in the Netherlands, FrieslandCampina. It introduced a Key Performance Indicator (KPI) system based on the conceptual framework to integrally direct the dairy farmer towards sustainability (Van Laarhoven et al. 2018). The KPIs indicate a farm's score on biodiversity and whether a farm is on track to meet the objectives set. The KPIs constitute an integrated set which collectively reflect biodiversity and more general sustainable performance. This means that KPIs are not applied individually; they balance each other out. KPI "percentage of protein produced on the farmer's own land" is an important KPI for Pillar 1 ("functional agrobiodiversity"), but can also serve as an incentive to increase grassland production per hectare, when in fact this could have a negative impact on biodiversity. By including the KPI "nitrogen surplus in the soil" and a KPI for "herb-rich grassland" in the set of KPIs, this potential negative side effect is offset. For dairy farmers focusing on the KPI "carbon equivalents per kilogram of milk," efficiency-focused measures would be an obvious choice, as increasing milk production while keeping the size of the cattle population roughly the same and with the same level of emissions will improve performance. A focus on efficiency could initiate intensification, which could have a negative effect on biodiversity and animal welfare. This is balanced out by KPIs related to the degree to which they rely on the land, e.g., the KPI "ammonia emissions per hectare" and the percentage of protein produced on their own land.

Conclusions

In this paper, I discuss nature-based agriculture as a way to provide high quality and healthy food within the limits of the environment. Healthy food is here defined as being more than safe and nutritious food and also includes the circularity of microbiology to provide a healthy microbiome in each part of the food cycle. Healthy diets require land-based food in order to maintain this microbial cycle. Landless food can contribute to provide a part of the required nutritious food in healthy diets, but it is hypothesized that nature-based food is essential to also maintain an adequate human microbiome.

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Compliance with ethical standards

Conflicts of interest/competing interests Not applicable.

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