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PERSPECTIVES

Food Sustainability in the Context of Human Behavior

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The long-term goal of food sustainability is to produce enough food to maintain the human population. The intrinsic factors to guarantee a sustainable food system are a fertile land, water, fertilizers, a stable climate, and energy. However, as the world population grows, the volume of food needed in the future will not depend just on these intrinsic factors, but on human choices. This paper analyzes some of the human actions that may affect the sustainable future of the food supply chain, including diet, obesity, food miles, food waste, and genetically modified organisms.

INTRODUCTION

In addition to food directly harvested from the wild, food is mostly produced at farms, and therefore, food sustainability is directly linked to sustainable agriculture. In 1990, the U.S. Congress addressed the issue of sustainable agriculture in the farm bill, which stated that "sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- provide human food and fiber needs;
- enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- sustain the economic viability of farm operations; and
- enhance the quality of life for farmers and society as a whole."

Based on the U.S. Congress' definition and the now famous 1997 United Nations' definition about sustainable development, which states that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs," definitions of sustainability have emerged in all sectors of the population.

Most businesses have embraced what is called the three dimensions of sustainability, or "triple bottom line," and some variations like "people-planet-profit," "the three pillars," or "the three E's," for economy, equity, and ecology. This idea is based on the premise that for a company to be sustainable it needs to be economically feasible, environmentally dependable, and socially responsible. The concept of the triple bottom line goes even further by allowing interchangeability, which means that if a business falls short in one of the dimensions, it can make up by "investing" in another dimension. For instance, a

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mining company is environmentally unsustainable in the long term because it depletes the resource. However, according to the triple bottom line concept, this company could compensate by making social contributions.

The general public has their own ideas of food sustainability, which often includes concepts like social justice, animal welfare, fair labor and trade, local farming, organic food production, and the concept of "natural," just to mention the most important ones. There is no official definition of natural. So different people have different ideas of the meaning of "natural." Another idea that most of the time is wrongly attributed to food sustainability by the general public is food miles. Many people believe the biggest impact on the whole environmental impact of food products is transportation and therefore favor local products, which in many cases is not necessarily true.

Regardless of definitions and beliefs, food sustainability is about generating food at a productivity level that is enough to maintain the human population. Sustainable food production is fundamentally grounded on the availability of fertile land, water, nutrients, and an adequate climate. In addition, the volume of food needed to feed humans is linked to intended or unintended human behavior. This paper analyzes some population attitudes and choices that have an impact on both the volume of food needed and the environmental impact to produce it.

THE EFFECT OF DIET

Besides their effect on health, different diets have different environmental impacts. One change in the global diet in the last 50 years has been the increased consumption of animal protein, which correlates with increased affluence around the world [1]. Production of animal protein is very tasking on the environment. One reason for this is the efficiency (or inefficiency) of conversion of feed into animal tissue, ruminants being the most inefficient animals to convert feed into muscle. On average, to produce 1 kcal of beef using a feedlot system, which is common in North America and is now becoming popular around the world, takes the input of 40 kcal of energy. Grass-fed beef takes approximately half of that energy. The advantage of ruminants is that they can ingest low-grade feed because they are capable of digesting cellulose. Monogastric animals like swine and poultry are more efficient at converting feed into muscle, but they require specialized diets with low cellulose content. Swine, turkey, and chicken need an input of 14, 10, and 4 kcal of energy respectively per 1-kcal output [2].

In addition to land use, livestock production has an enormous role in soil destruction, water depletion and pollution, impact on biodiversity, and a disturbance of the nitrogen and carbon cycles. Livestock grazing occupies the equivalent of 26 percent of ice-free surface of the planet in addition to 33 percent of arable land dedicated to the production of feed crops [3]. Besides land use, cattle raising has a profound impact on soil properties. The constant animal traffic, especially cattle, compacts the soil, which reduces water infiltration and promotes runoff. Runoff not only translates into soil erosion but also carries nutrients to surface water [3].

Ruminants, in particular, are major producers of greenhouse gases through enteric fermentation. Besides carbon dioxide, a byproduct of enteric fermentation is methane, which has a greenhouse potential twelve times higher than carbon dioxide. Ammonia is another gas resulting from animal production. Ammonia is not a greenhouse gas but has local and regional effects and is responsible for alteration of the nitrogen cycle [2].

One way to reduce the environmental impact of animal production would be a diet with more vegetable protein. One disadvantage is that vegetable protein does not have a complete amino acid profile, thus requiring the right combination to have all the essential amino acids in the diet. A second disadvantage is that vegetable proteins are more difficult to get broken down by the human digestive system. Nevertheless, perhaps the most difficult issue that we humans confront in the reduction of consumption of animal products is the undeniable preference we have for animal protein.

Insects are another source of protein used in many countries around the world but not very well accepted yet in western countries. Insects have a significant advantage in terms of lower environmental impact in relation to traditional livestock. Insects need much less water and produce fewer greenhouse gases and ammonia emissions. According to one source, the emission of greenhouse gases from insects is 1 percent of the emissions of ruminants for the same amount of protein [4].

OBESITY AND OVERCONSUMPTION

Worldwide, an estimated 1.9 billion adults, 18 years and older, are overweight, and out of these over 650 million are obese. More alarming is the fact that 41 million children under the age of 5, and more than 340 million children and adolescents aged 5 to 19 were reported overweight or obese by the WHO in 2016 [5].

Weight increase and obesity is the result of consuming more calories than the calories spent in physical activities. Most foods can cause weight gain, but the main offenders are calorie dense foods. According to FAO, Americans eat an average of over 3,600 calories a day, which is well above the U.S. Department of Agriculture recommendations of 2,000 to 2,600 calories per day for a sedentary adult male and 1,600 to 2,000 for a sedentary adult female [6]. Besides consuming too many calories, Americans, especially children, are getting their calories from calorie dense foods and sweetened beverages made with fats and sugars [7].

The growing obesity pandemic presents one more challenge for agricultural sustainability. In addition to keeping up with food production to tend to a growing population, more food will be needed to maintain population's extra weight.

Overweight and obesity have both significant health and environmental implications. Being overweight decreases physical activity and personal mobility leading to increased use of motor vehicles [8]. Even airlines have recognized the effect of the increased average weight of passengers on fuel consumption [8]. Other scientists are studying the impact of obesity on the environment from direct emissions of CO_2 through respiration, which is proportional to body mass. According to results reported by Gryka *et al*. [9], a 10-kg weight loss of all overweight and obese people would translate into a 0.2 percent reduction in the global CO_2 emissions. Although this percentage is small, the main issue, however, is the extra burden placed on the environment to produce, process, and transport additional food to provide the extra calories required by overweight populations.

A 2009-study reported that an overweight population with an average body mass index of 29 needs 19 percent more calories than a normal population with a body mass index of 24.5 [10]. To produce these extra calories, more land, water, fertilizer, and fossil fuels are needed.

LOCAL VS. TRANSPORTED

It is often believed that locally produced foods have a lower environmental impact than food grown or raised somewhere else and transported; and "food miles" is the indicator commonly used to illustrate how far the food has traveled from production to consumption [11]. Nevertheless, does the food produced locally have a lower environmental impact than food produced in other regions and transported? The answer is it depends on the food product and the transportation mode. As a general rule, the faster the transportation mode the higher the environmental impact it produces. Regarding energy used, planes have the highest consumption per ton of food transported followed by trucks, trains, inland barges, and maritime ships [2].

Because of the perishable nature of foods, not all food products can be transported with all transportation modes. Dry materials, such as grains, can be carried in barges or maritime ships. Fresh produce and fruits, on the other hand, have to rely on faster transportation modes such as trains, trucks, and planes [2]. On average in the U.S., the energy used to transport foods represents only 14 percent of the total energy used to produce, process, distribute, and prepare the food at home, restaurants, and institutions [12].

Another factor to consider in the debate of local vs. transported is climate and seasons. Fruits and vegetables cannot be grown in high latitude climates in open agricultural fields during winter. The only alternative is to use greenhouses or to transport the food from temperate climates. If grown in greenhouses, plants need supplemental light and heat with the resulting expenditure of energy and the emission of greenhouse gases.

Other foods are more favorable to be produced throughout all the seasons in specific parts of the world. A classic example is lamb meat produced in New Zealand vs. in the UK. Even when grazing is the main source of nutrition for both countries, pastures are more productive in New Zealand due to more solar irradiation and less use of synthetic fertilizers. Therefore, an advantage may exist in terms of lower environmental impact for lamb produced in New Zealand instead of the UK even when factoring transportation by ship to the UK [13].

Another consideration is seasonality. In this day and age, especially in developed countries, and as a result of low-cost transportation and logistics, most food products are available all year round. Due to their short shelf life, fruit and vegetables are in most cases transported by plane with the associated environmental impact. On average, the operational energy of a long-haul cargo plane, expressed in MJ/metric ton-km, is around four times more than a truck and 30 times more than a train [14].

FOOD WASTE

According to estimates, of the 200 million metric tons of food produced annually in the U.S., 60 million metric tons go to waste [15]. From the analysis of food waste that reaches landfills, 47 percent of the waste comes from the residential sector [15].

Clearly, not all food waste is edible. Food waste can be classified into three main types: avoidable, possibly avoidable, and unavoidable. Avoidable waste is food or drinks that before disposal were perfectly edible or drinkable and for no particular reason were discarded. Potentially avoidable are parts of foods that are eaten by some people and discarded by others. For instance, some fruit peels are edible, but some people prefer not to eat them. The third category, unavoidable food waste, encompasses inedible parts of the food like bones, eggshells, inedible peels, and spent coffee grains [16].

What are the reasons for the food waste generated by the residential sector? There are several, the most important ones being: availability of inexpensive food, poor purchase planning, perishable nature of foods, and confusing shelf life statements.

It is fair to say that the main drive to food waste at the household level in the U.S. is that food is inexpensive.

According to USDA data, the disposable income to buy food to eat at home has decreased from 10 percent in 1970 to around 6 percent in 2009 [17]. In the same period, food waste increased by 50 percent [18]. It is important to point out that in the same period, food eaten away from home rose only from 3.5 to 4 percent [17].

Another reason food purchased to be consumed at home is often wasted is a combination of lack of purchasing planning and the nature of perishable food, especially fruits and vegetables. Very often, this is exacerbated by packages containing a large volume of food at a reduced price, which is often offered in wholesale clubs.

Most foods in the U.S. have some shelf life statement such as "use by," "sell by," or "best by" date. "Use by," mostly used in meat, fish, and cheese, is a firm expiration date that is related to the safety of the food. "Sell by" is a statement aimed at retailers, which informs them when the product has to be pulled from the shelf. Typically, one-third of the product's shelf-life remains after the sell-by date for the consumer to use at home. "Best by" is an indicator to the consumer about when the product will have an optimal quality [19]. Unfortunately, most consumers are not acquainted with the exact meaning of these terms and take them as firm expiration dates. As a consequence, they do not buy the products close to these dates, or they discard the food products once they reach the "sell by" or a "best by" date [19].

Besides being morally questionable, food waste uses resources to produce and transport extra food such as land, energy, water, and fertilizers with the consequent emission of greenhouse gases. At the end of the cycle, wasted food needs to be transported and disposed of with subsequent land use, fuel use, and emission of greenhouse gases from trucks, machinery, and decomposing food [18].

GENETICALLY MODIFIED ORGANISMS

Projections indicate that the world population will increase to 9.2 billion by 2050. To provide food for this growing population, a substantial increase in agricultural production will be required. Scientists have estimated that the agricultural production has to grow at a rate of 1.1 percent annually to cover food demand in 2050 [20].

Agricultural biotechnology based on genetically modified organisms (GMOs) offer new prospects and opportunities to increase the productivity of agriculture while decreasing the environmental detriment caused by current agricultural practices. Genetically modified organisms, also known as "genetically modified food," refer to the alteration of the genetic makeup of crops by the insertion of novel genes from other sources or deletion of existing genes. Scientists and farmers agree that there are many advantages in applying biotechnology in the food industry, including the possibilities of solving the world's hunger problem, developing superfoods with added vitamins and nutrients, while generating economic growth for the farmers [21].

The first generation of GMO crops, mainly GMO soybeans, canola, corn, and cotton were approved for commercialization in 1996. The goal of this first generation of genetically modified crops was primarily the improvement of pest management such as herbicide tolerance, insect resistance, some yield enhancement, but not profitability. The rapid adoption of these technologies in agriculture demonstrated their benefits to farmers around the world, but did not have a tangible benefit to the consumers. The second generation of GMO crops focused on output traits such as enhanced nutritional features and processing characteristics. These had no impact on profits received by farmers because the products are indistinguishable from conventional crops. The most recent third generation of genetically modified crops, which are currently produced only at small scale, includes plants engineered to generate specialty chemicals, including biodegradable plastics, adhesives, and synthetic proteins. A particular subset of the third generation of GMOs, also known as "Pharmacrops," has been genetically modified to produce vaccines and antibodies [22].

Despite its benefits, controversial debates on the advantages of GMOs persist. After two decades using and developing GMO crops, some social and environmental implications have recently raised serious concerns. Some of the negative socio-economic effects include corporate dominance, land concentration, loss of farm jobs, and an increase in income inequality. Many argue that it is still too early to know for sure if GMOs will not have an adverse impact on the environment and human health in the long term. Environmentalists have expressed their growing concern regarding the possibility of engineered genes exposure to wild populations. Others fear that the use of biotech crops will affect the biodiversity by the persistence of genes after a GMO has been harvested, the susceptibility of non-target organisms, and the instability of new genes. As for human health, the main fear has been the creation of new allergens and the gene transfer from GMO foods to human cells or the intestinal microflora. Another hazard is the transfer of genes from GMO plants into conventional crops, as well as the mixing of GM crops with those derived from conventional seeds, which could have an indirect effect on food safety and food security [22].

GMOs promoters, on the other hand, consider biotechnology agriculture a crucial tool to enhance crop productivity, food quality, and the production of vaccines and therapeutic medicines. GMO crops advocates claim that there is enough evidence that GMOs are essential for promoting sustainable agriculture since it can decrease agriculture's environmental footprint by reducing the use of pesticides, saving fossil fuels, lowering CO_2 emissions and conserving soil and moisture [21].

Even though GMO crops are not presented as the "absolute solution," they could undoubtedly make a significant contribution to find a solution to the global food security problem. A recent meta-analysis of 147 published biotech crop studies from 1995 to 2014 concluded that biotech crops have generated multiple and tangible benefits over the past 20 years [23]. According to this study, on average, the adoption of GMO technology has reduced the use of chemical pesticides by 37 percent, increased crop yields by 22 percent, and increased farmer profits by 68 percent. There are also health benefits for farm workers as a result of less chemical pesticide spraying [22]. The adoption of GM insect resistant and herbicide tolerant technology has reduced pesticide spraying by 581.4 million kg (8.2 percent reduction), and the environmental impact associated with herbicide and insecticide use on these crops, measured by the EIQ indicator, dropped by 18.5 percent since 1996 [24].

In spite of the fears, very likely GMO technology will play an increasingly significant role in agricultural sustainability in the years to come. This technology offers the opportunity to generate new crop varieties that would be more resistant to pest or drought, and consequently will increase and enhance productivity yields to ameliorate hunger and the food insecurity problem worldwide.

CONCLUSION

The food system, particularly in terms of emission of greenhouse gases, has impacts at all stages of the supply chain. However, the agricultural stage is the single largest greenhouse gases emitter with meat and dairy products as the most greenhouse gases-intensive foods. Nevertheless, the role of humans and their consumption patterns have a significant impact on the production of food and the population set of beliefs and attitudes will dictate whether or not the long-term sustainability of the food supply chain can be achieved.

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