A System Dynamics Model of Impacts on Environment Related to Thais' Food Consumption

Piyanit Churak
Institute of Nutrition,
Mahidol University, Nakhon Pathom, Thailand

Nobuo Nishi
Center for International Collaboration and Partnership
National Institute of Health and Nutrition, National Institutes of Biomedical Innovation, Health and Nutrition, Tokyo, Japan

Abstract

Food insecurity would be affected by environmental impacts of the food system because insufficient food production yields to the number of consumers. This study aimed to develop a simulation model of greenhouses gas (GHGs) emission related to food consumption of Thais by population age group and simulate scenarios of changing food consumption with the altering outcomes on environment. Aging chains were made by age group of infants, children, adults and elderly and GHGs from food consumption were calculated. Population for each age group and their consumption were optimized to actual numbers. Simulations were set at 2006-2030. The overall emission was higher than that of Food-based Dietary Guidelines (FBDGs). The contribution was the highest from adults. The four scenarios were made by changing amount of food consumed. Reducing meat intake and substituted energy intake by vegetables has influenced to decrease of emission. Decreasing of beverages in children and adults provided the drastic change in decreasing GHGs. Additional increase of milk intake by elderly had affected to GHGs level in a few numbers. Food choices may ultimately result in impacts on the environment. It is therefore recommended that environmental friendly consumption practices should be encouraged for human well-being and food security.

Introduction

Climate change and natural disasters are extremely worrisome. The global climate is warming up due to the effect of greenhouse gas (GHGs) emission. In Thailand, the GHGs by the sector of activities have been reported (1). About 70% is from energy sector, which is from industry, electricity, and fuel use activities. And the 2nd highest in percentage is from the sector of agriculture forestry and other land use change (AFOLU). Cropland and rice cultivations, sub sectors of AFOLU, account for more than 60% and other 30% is from the livestock sector.

Besides AFOLU, which is a kind of production stage during the food life cycle, several human-induced activities cause the emission of GHGs during the life-cycle of food, such as agricultural technologies, food processing, transportation and distribution to the consumers.

Indeed, throughout the world, there appears to be a direct link between dietary preference, agricultural productions as well as activities during food production until the end process at disposal and environmental degradation (2, 3). As the explanations of environmental nutrition model (Figure 1), this proposed the interaction between food systems, the environment, and public health. Food insecurity would be affected by environmental impacts of the food system because insufficient food production yields to the number of consumers. Since, food, nutrition, and environment issues are relevant to people's wellness, population study concerning to their influence on environment is needed. System dynamics is suitable for simulation of population dynamics, but it is rarely used in public health in Thailand. This study aimed to develop a simulation model of GHGs emission related to food consumption of Thais by population age group and simulate scenarios of changing food consumption with the altering outcomes on environment.

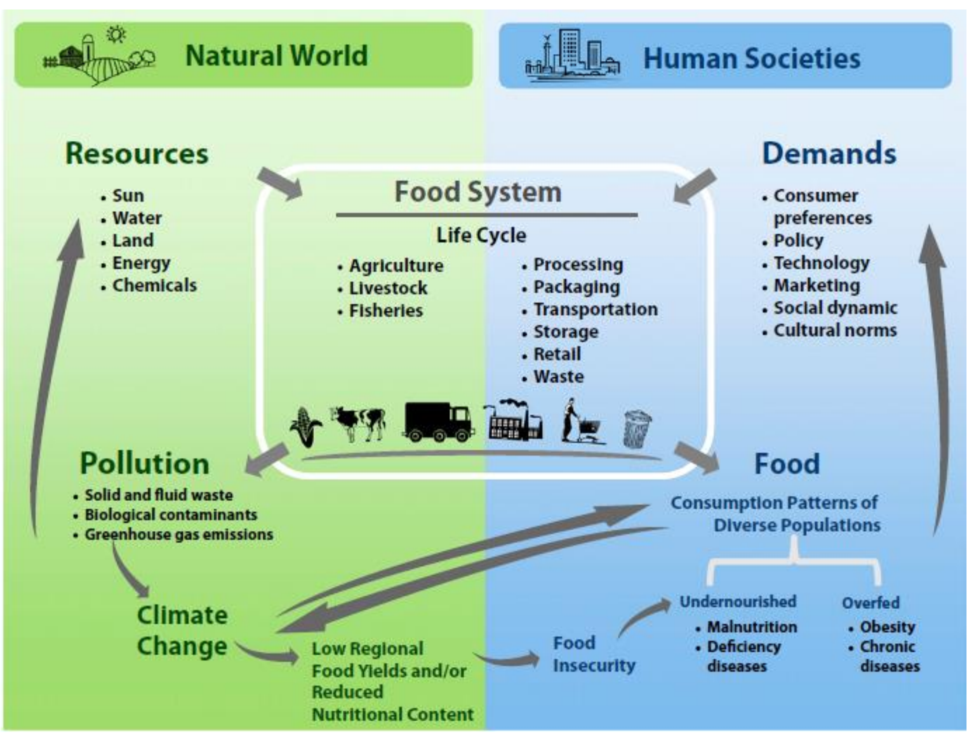

Fig. 1 The environmental nutrition model proposed by Loma Linda University (3)

Model structure

A model was developed for simulating dynamics of GHGs emission according to food consumption of Thais aged 3 years and over from 2006 to 2030, obtaining data from food consumption in Thailand between 2006 and 2015 (4, 5). The population was divided into four groups as the aging chains of infants (birth to 2), children (aged 3 to 18), adults (aged 19 to 64) and elderly (aged 65 to 99). Each population group has own food consumption pattern, it is thus to separate their own part for children, adults, and elderly. It was assumed that infant consumption might have minor effect to environment because their main energy intake might be from breast milk and/or complimentary foods. Moreover, the amount of food consumed by infants might be a little compared to other population groups. With a similar reason in food consumption by the elderly who aged 100 years and over, it is therefore infants and the elderly aged 100 years and over was not included in the simulation. Even if each population group has definitely separate consumption and emission part with each other, basic elements were similar except for some variables such as amount of food consumed. To calculate emission by each population group, each group had 9 stocks that represented amount of food consumed in each food group. They were grain and cereals, vegetables, fruits, meats, milks, confectionaries, fats and oils, beverages, and sugar and sweeteners. Details of calculation are described in 'Food consumption and GHGs emission factors' section below. An overall model structure is shown in Figure 2, and a food consumption and GHGs emission part structure for children is shown as an example in Figure 3.

Population aging chains

This study used aging chains to keep track of population change. A stock represents population at each age group including infants (birth to 2), children (aged 3 to 18), adults (aged 19 to 64) and elderly (aged 65 to 99). Each population stock has three flows: one inflow and two outflows. The one inflow directs from the neighboring younger age group. One outflow is from each age group to the neighboring older age group. And another outflow is for deaths in each age group. An exception was made for the elderly stock. It contains only two flows; one inflow from neighboring younger age group and one outflow for deaths due to a reason mentioned in model structure description. Every population stocks were linked to a variable 'birth' because of rates used in the model are crude birth rates.

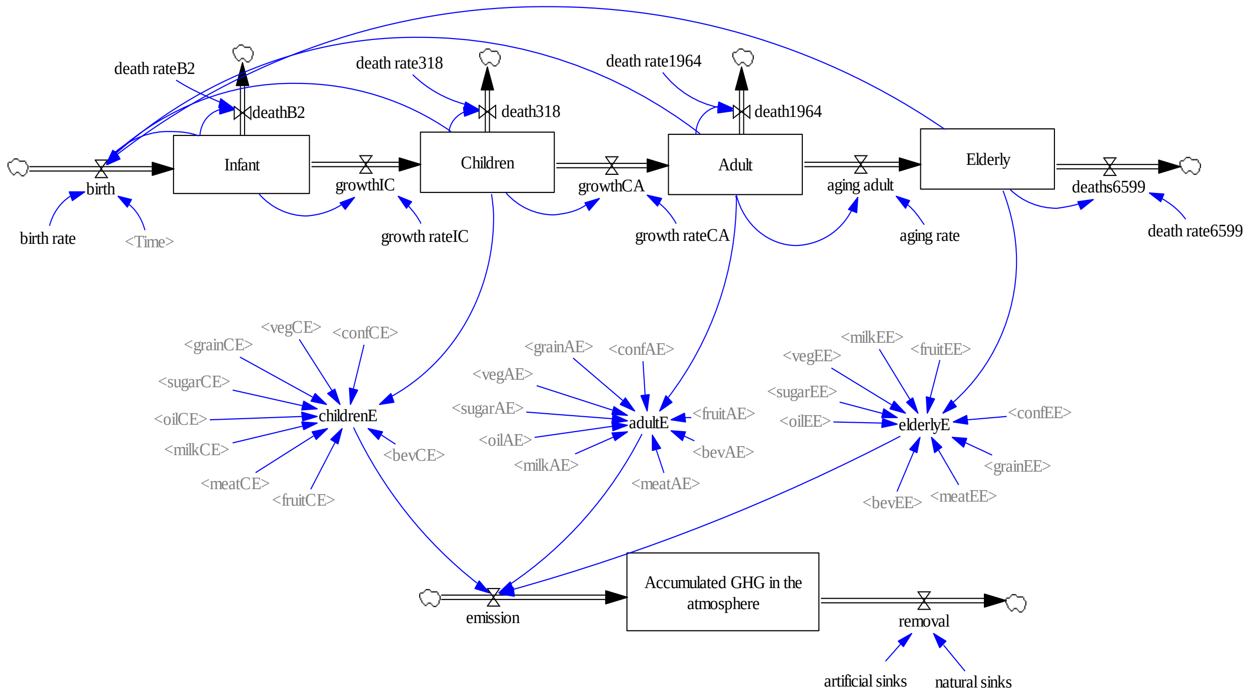

Fig. 2 Overall model structure

Food consumption and GHGs emission factors

GHGs emission from population consumption was calculated based on the aggregated outcome of food consumption of each population group multiplied by its emission factor. The unit of food consumption and its emission were set. Each of unit composed of one inflow and one outflow (for example, a grains and cereals consumption of children stock [grainC] has an inflow [grainCI] and an outflow [grainCO]). Based on the most popular food choice in each food group, a representative emission factor was applied to each of nine food groups. The representative foods were rice for grains and cereals, cucumber for vegetables, watermelon for fruits, pork for meats, plain milk for milks, palm olein oil for fats and oils, refined sugar for sugars and sweeteners, Thai fried banana (Kluay kaek) for confectioneries, and cola for beverages.

Optimization

An optimization was performed to adjust model parameters based on actual data. It was performed for population aging chains using multipliers of each age group to their actual population. And food consumption was also optimized using multipliers of each food group to their actual consumption of each food group in children, adults, and elderly.

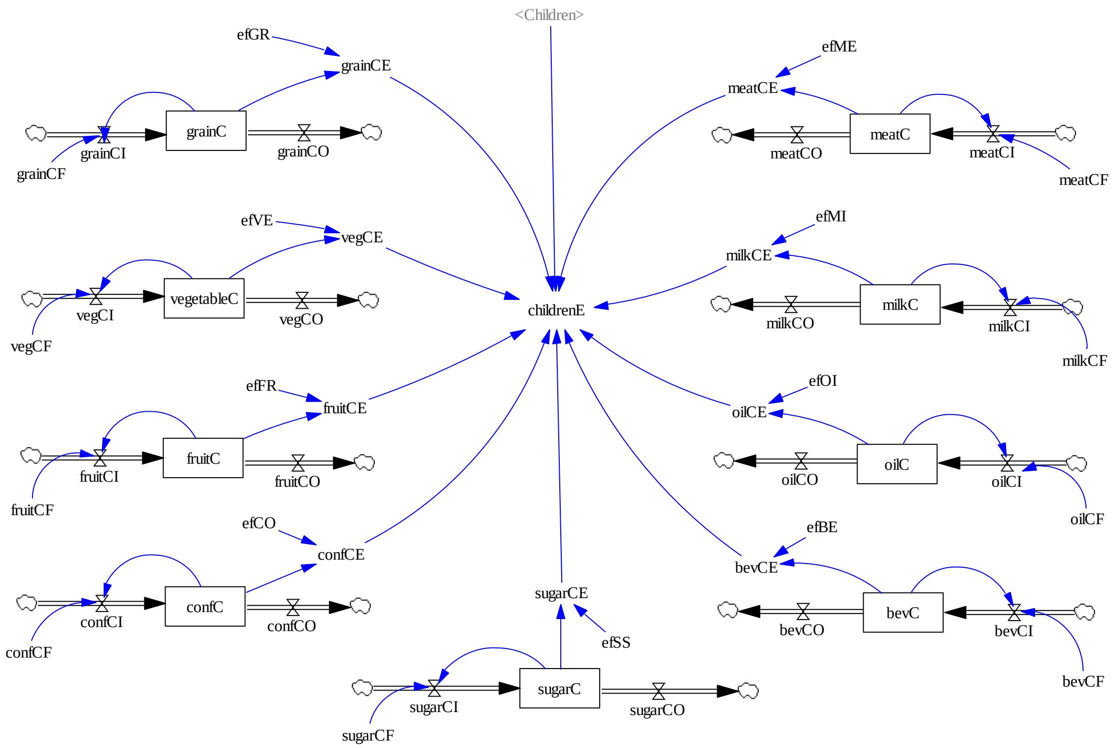

Fig. 3 Example of food consumption and emission part structure (Children)

Model simulation

1. Emission of usual food consumption

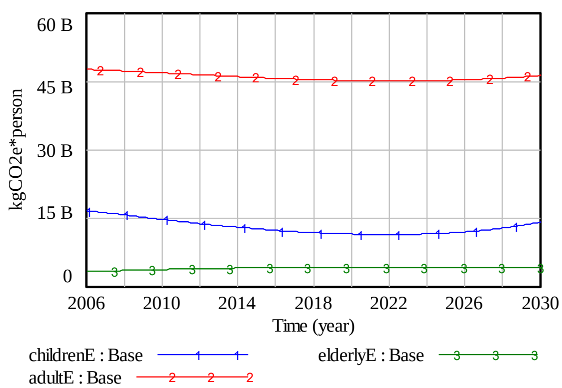

Fig. 4 Total GHGs emission by population group

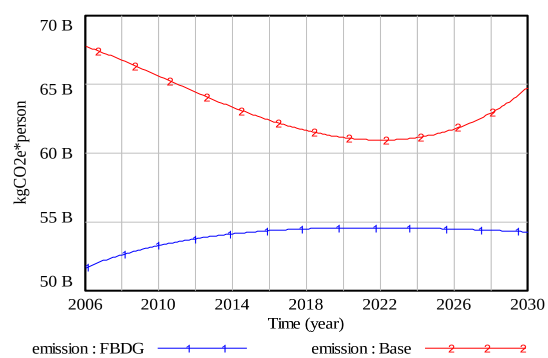

Fig. 5 Total GHGs emission of population and emission of food-based dietary guidelines

According to usual food consumption of Thais, the GHGs emission of population group is shown in Figure 4. The contribution was the highest from adults since they are the majority group of population. The overall emission, however, was higher than that of Food-based Dietary Guidelines (FBDGs) for Thais (6). Trends of emission has decreased since 2006 and it is projected to rise again after 2022 (Figure 5).

2. Simulation in four scenarios

There were four scenarios, which were developed by changing some food consumptions with consideration of maintaining energy intake as base consumption. The four scenarios were reducing of meat consumption in adults, reducing of beverages consumption in children and adults, increasing of milk consumption in elderly, and reducing of beverages consumption in children and adults and increasing milk consumption in elderly.

2.1. Reducing of meat consumption in adults

The first scenario assumes that adults reduce 3% of their meat consumption. Thus, to keep up total energy intake from foods, increasing in other food groups are needed. Vegetables was chosen to consume more because vegetables seem to be the low carbon emission choice. Changing in amount of meat consumption is shown in Figure 6, and Figure 7 is for consequence in total GHGs emission. Because most vegetables have low carbon emission as a result of using less resources during food lifecycle. The GHGs emission decreased after reducing in meat while increasing vegetables consumption.

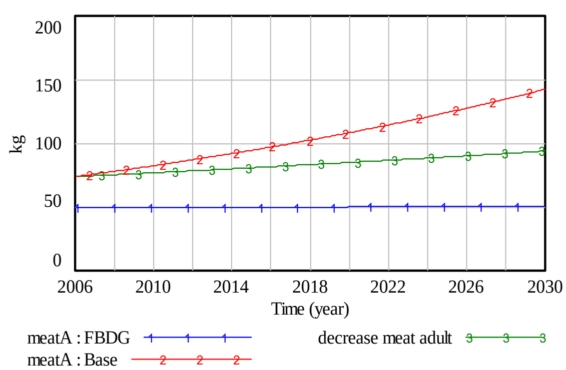

Fig. 6 Change of meat consumption in adults

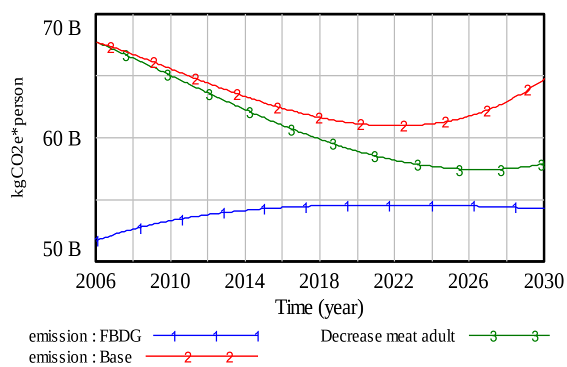

Fig. 7 Change in total GHGs emission after decreasing of meat consumption in adults

2.2. Reducing of beverages consumption in children and adults

In the second scenario, on the strength of, beverages consumption both in children and adults increased especially in children. And as most beverages in Thailand are sweetened drinks, which is one cause of obesity. The scenario assumes that both population groups reduce 25% of beverages consumption. Moreover, to promote healthy drinks like milk and consumption of milk in adults is below recommendation, increase in milk intake in adults was chosen. Changing of relevant food consumptions by this scenario are shown in Figure 8, 9 and 10. Beverages intake drops both in children and adults when consumption of milk increases. Nonetheless, it is still lower than recommendation of FBDGs. The total emission continually decreases from base consumption (Figure 11).

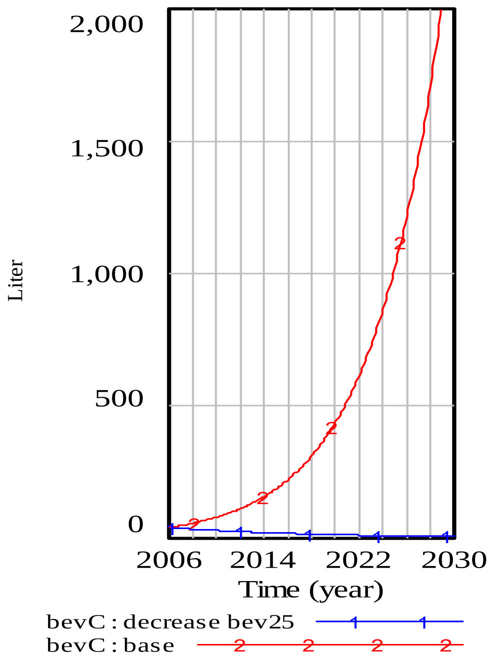

Fig. 8 Change in beverages consumption in children

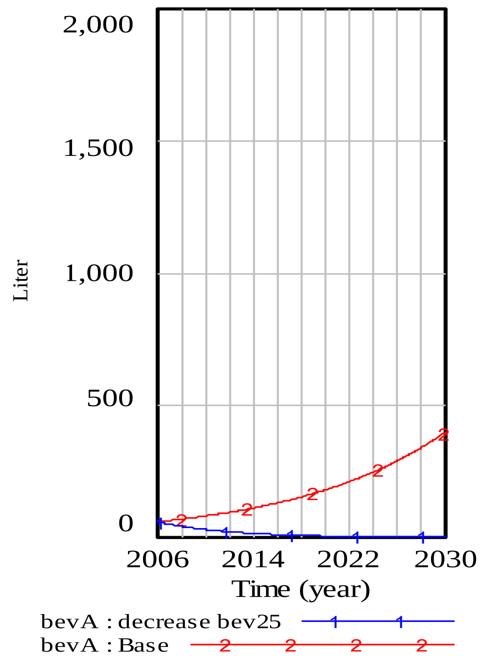

Fig. 9 Change in beverages consumption in adults

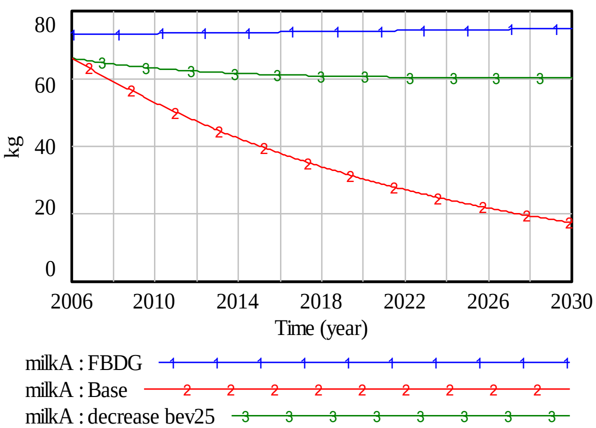

Fig. 10 Change in milk consumption in adult

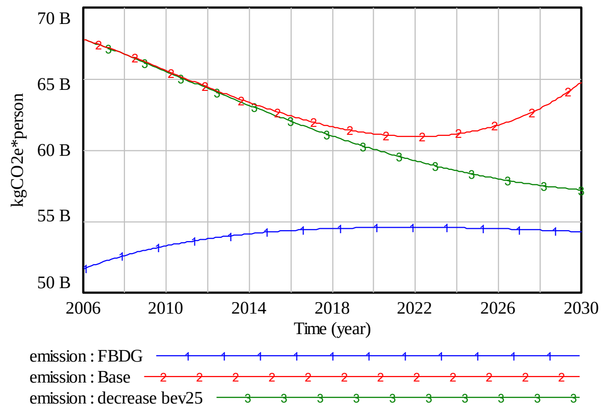

Fig. 11 Change in total GHGs emission after reducing of beverages consumption in children and adults

2.3. Increasing of milk consumption in elderly

As calcium is essential for elderly but actual consumption is very low. Milk and its products which are the high sources of calcium ought to increase. This scenario enhances the milk consumption in elderly for 50% of usual intake. Their consumption will rise to meet the requirement in the year of 2026 as shown in Figure 12. It leads the result of a little change in higher total GHGs emission than that of base food consumption (Figure 13). It seemingly confirms that even if food intake increases in large number, it does not mean that the emission will change greatly. It is up to food choices.

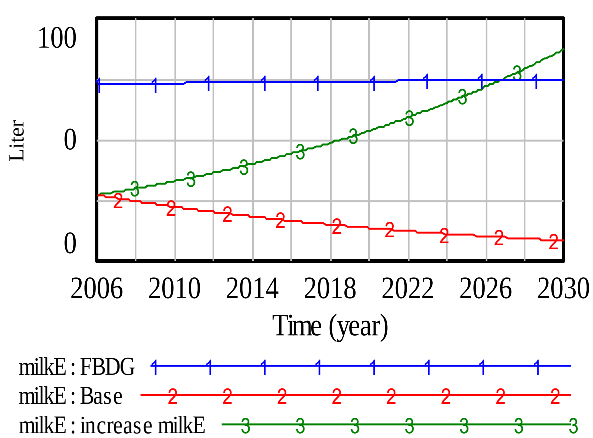

Fig. 12 Change in milk consumption in elderly

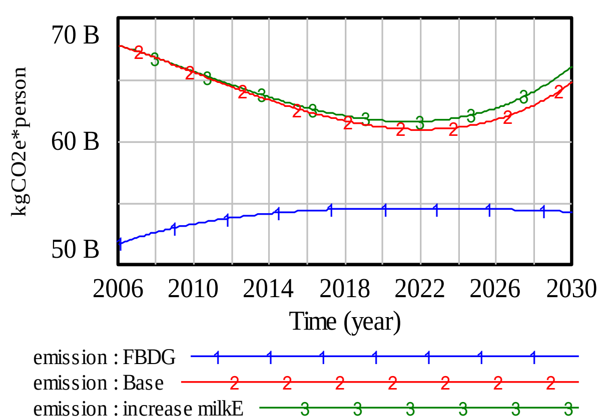

Fig. 13 Change in total GHGs emission after increasing milk consumption in elderly

2.4. Reducing of beverages consumption in children and adults and increasing milk consumption in elderly

The last scenario is a combination of scenarios 2 and 3 to simulate the overall GHGs emission if these scenarios happen at the same time (Figure 14). The emission in the combination scenario relies on effect of decreasing beverages, and it was a little higher than the emission of decreasing on beverages only. Anyhow GHGs emission of this scenario is still higher than that of

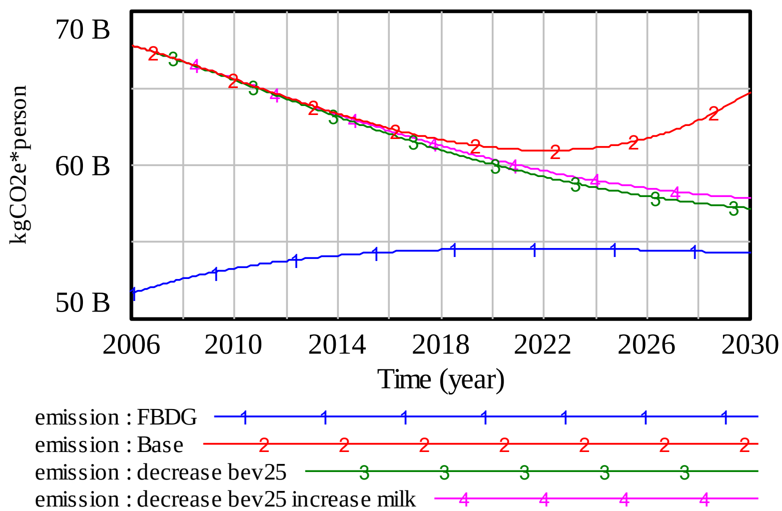

Fig. 14 Change in total GHGs emission in combination of scenarios

FBDGs.

Over-consumption provides more emission and might affect nutritional status and also their health. It reflects the results from national health examination survey which shows a trend that overweight and obesity is still rising over 25 years (7-9). Besides eating less and less, increasing physical activity is recommended to reduce GHGs emission from food consumption. For example, shorten the food lifecycle by walking to market or local farm near your place instead of using cars or limiting food choices to imported foods. It could reduce emission from food transportation, meanwhile, increasing physical activity.

Conclusion

Food choices may ultimately result in impacts on the environment. It is therefore recommended that environmental friendly consumption practices should be encouraged for human well-being and food security.

Acknowledgement

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