Macro-economic, socio-economic, environmental and health trade-offs in different diet scenarios in Bangladesh using a CGE modelling approach

Thijs de Lange

In this study we analyze the trade-offs between a EAT Lancet flexitarian diet and a high income country (HIC) diet, with a high share of red meat, dairy, poultry and wheat, for Bangladesh by a general equilibrium model. The HIC diet is more expensive compared to the FLX diet, mainly driven by a strong increase of red meat and dairy. In addition, the results indicates that poverty reduction is higher and inequality is lower in the FLX diet scenario, as result of a relative higher increase for low skilled labour compared to the price increase of average food and non-food commodities. Looking at the environment, total GHG emissions are higher in the HIC diet scenario as a result of higher red meat production, however the emissions of non-food production is higher in the FLX diet scenario driven by a higher demand in this scenario. Land pressure increase more in HIC diet scenario although the differences with the FLX diet are small. Fertilizer use is higher in the FLX diet scenario driven by nuts and seeds, and vegetable production.

Introduction

Economic growth and a growing middle class are expected to increase the demand for animal protein, non-traditional grain (e.g. wheat), and processed food in Low and Middle Income Countries (LMICs) (Tschirley et al. 2015). The worldwide rise in animal protein consumption is projected to lead to further biodiversity loss, as a result of overuse of natural resources like water resource depletion and deforestation, and an increase in greenhouse gas (GHG) emissions (Willett et al. 2019). Additionally, the increase in imported grain demand might lead to food systems becoming more vulnerable to shocks. Lastly, the increase in demand for ultra-processed food leads to a subsequent increase in obesity and in the double burden of malnutrition and nutrient-related non-communicable diseases (Popkin 2020). The latter are driven by the availability of ultra-processed food in combination with reduced physical activity.

Over the last decades, Bangladesh has experienced strong socioeconomic growth and impressive poverty reduction. As a result, Bangladesh has made significant progress in reducing malnutrition (Nguyen et al. 2022). However, there are still deficiencies in dietary diversity and micronutrient intake. The majority of the population consumes less than 75% of the recommended dietary intakes for all food groups with the exception of starches. Simultaneously, 22%, 17% and 14% of the population consume more than the recommended intake of sweets, oils and meat, respectively (de Brauw et al. 2020). These overconsumptions are mainly caused by the increase in household income and urbanization, and have led to a sharp increase in the prevalence of overweight and obesity (Nguyen et al. 2022). As a consequence of this, the incidence of non-communicable diseases like hypertension and diabetes has risen in the last decades (Nguyen et al. 2022; Ahsan et al. 2022). Similar to other

LMICs, the prevalence of overweight, obesity, hypertension and diabetes was the highest in wealthier households (Nguyen et al. 2022). This is a result of changes in household purchasing power and food environment, that in turn have led to a change in consumption patterns, as well as a decrease in physical activity, especially in urban areas.
Urbanization and change in lifestyle also affect staple crop consumption in Bangladesh. There is a growth in the demand of wheat: annual per capita wheat consumption has increased from 8.62 to 17.47 kg between 1961 to 2013, and it is expected that demand will growth further. For this reason, Bangladesh is currently to a great extent dependent on imports; for instance, around 80% of the total wheat supply is imported. However, the possibility for domestic wheat production increase is constrained by various factors like terminal heat stress, salinity and competition of other crops (Barma et al. 2019). In addition to wheat, meat and dairy have also seen an increase in their domestic consumption. Between 2010-2011 and 2017-2018 the production of these increased from 1.99 Mt to 7.26 Mt and from 2.95 Mt to 9.41 Mt, respectively (de Brauw et al., 2019)

Although Bangladesh made progress in reducing malnutrition, new challenges arise from changing diets. The transition towards a healthy and sustainable diet might bend the curve of the growth in overweight/obesity and environmental effects related to animal protein production. However, a healthy diet is not always affordable for the world's poor, at least 1.58 billion people cannot afford an EAT-Lancet diet (Hirvonen et al., 2020). In addition, stimulating such diets can increase the use of local resources, especially in low-income countries (Springmann et al. 2018). Although various studies analyzed the trade-offs between health and environmental indicators of healthy diets (Springmann et al. 2018; Clark et al. 2019), these do not capture economic trade-offs.

The objective of this study is to identify macro-economic, socio-economic, environmental and health trade-offs between different diet scenarios in Bangladesh by analyzing indicators like dependency on trade, employment, food affordability, land and water use, GHG emissions and mortality using a CGE modelling approach.

Methodology

Model setup
We used the global general equilibrium model MAGNET (Woltjer et al. 2014) to analyze the trade-offs between two diet scenarios for Bangladesh. The core of MAGNET is the GTAP v7 (Corong et al. 2017) and the GTAPv10A database, base year 2014 (Chepeliev 2020). The extension of the model is mainly in the domain of agriculture, food security and bioeconomy (references, xxx). Key characteristics in this model essential for this study is endogenous land markets, capturing the dynamics between agricultural land supplied and real land prices including the total potential suitable land available for agriculture (van Meijl et al 2006, Dixon et al 2016) and segmented factors markets in agricultural and non-agricultural labour and capital, given the empirical evidence that the mobility of labour is imperfect (De Janvry et al., 1991). In addition, for the five occupation types in MAGNET, the labour data is extend with number of workers per sectors (www.impactecon.com).

Given the focus of this study, the sector aggregation used is detailed for the primary agriculture, food processing, fisheries and industry sectors related to the food system, while sectors not directly related to the food system sectors are aggregated to less detail (see table XXX). The model includes 16 aggregated regions: Ethiopia, Kenya, Uganda, Nigeria, Ghana, Viet Nam, Bangladesh, Pakistan, India, Indonesia, Brazil, High income countries, Asia and

the Pacific, Latin America and the Caribbean, Near East, North Africa, Europe and Central Asia, Sub-Sharan Africa.

Diet scenarios

The two diet scenarios we used in this study is a high income (HIC) diet and the flexitarian (FLX) diet of the EAT-Lancet diet locally adjusted for Bangladesh both derived in Springmann et al. (2021). Because we are interested in analyzing the effects of change in the composition of stable food consumption in the high-income diet, we subdivide the staple food target in the sub-groups wheat, rice, maize, other grains and roots based on the benchmark diets from the SI from Springmann et al. (2021). In summary, the HIC contains a high demand for of red meat, dairy, sugar, oils and fats and wheat, while the FLX diet has a high demand for vegetables, fruits, legumes, nuts and seeds and fish (see table XXX). The baseline diet

Table 1: Baseline diet (2018), the Eat Lancet Flexitarian diet (FLX general) and the two diet scenarios Flexitarian diet adjusted for Bangladesh (FLX Bangladesh) and the average diet for high income countries in 2017 (HIC 2017)

Food groups	Baseline diet (2018)	FLX General 2050	FLX Bangladesh 2050	HIC 2017
Cereals	495	232	347	267
Rice	448			44
Wheat	44			115
Other Grains	2			21
Roots and Tubers	125	50	75	57
Vegetables	70	300	300	195
Fruits	61	200	200	143
Pulses	16	75	75	13
Nuts	2	50	50	12
Oil seed	42	40	47	47
Sugar	22	31	27	80
Fish	50	28	43	33
Dairy	59	250	59	216
Red meat	9	14	12	98
Poultry	10	42	16	94

Analyse spill over impact of food demand and set diet target with Leontief inverse

The basis of global CGE models are global multi-regional input-output (MRIO) databases. Global MRIO gives detailed information on the inter-linkages between consumption and production including information on imports and exports. The use of global MRIO in combination with additional satellite accounts of various indicators allows to analyse 'spill-over impact' final demand in the supply chain and is extensively used in lifecycle studies. In contrast to studies using global MRIO databases, the use of CGE models can be used for

ex-ante studies by taken into account various drivers (like population growth) and behavioral responses. One of the trade-offs we want analyse in this study are the environmental effects of food consumption. Imported food contributed to a significant share to the Bangladeshi diet. To take into environmental effects of imported foods on foreign countries we conduced an ex-ante footprint analysis by using the multi-regional input-output tables (MRIO) in combination with satellite accounts of various environmental indicators.

Besides the purpose to analyse the 'spill-over impact' of food demand, we used the composition of the demanded food derived with the Leontief-inverse to target the diets on food group level. In MAGNET, significant amount of the consumed food is processed and is often made from several primary food commodities. The commodity processed food (ofd) contains a wide range of food from frozen vegetables to highly processed ready-made meals. This results in the production per unit ofd uses various primary and processed food commodities. In addition, the production of processed food like poultry meat (pltrymt) uses next to the primary commodity poultry also small amounts of other commodities which influences the nutritious value of the commodity. After each period run, the composition of processed food changed in primary agricultural commodity content as well the country of origin. By using the leontief inverse, the primary food composition of processed food items can be derived. For specific this case, we excluded the input used to produce primary food, like cereals used for the production of meat. In this way we could target the consumed diet on food group level as detailed as possible.

Results

In both scenarios the wages are increasing for the lowest income class (the agricultural and low skilled workers in the agricultural sector) and the accessibility of staple food and affordability of the diets are increasing. However, induced by the increase in total food consumption as a result of population growth and the changes in diets, in both scenarios the total GHG emissions, fertilizer use and land demand are increasing. At the same time the self-sufficiency ratio of the total kcal consumption decreased, meaning that the food consumption of households are more depending on trade in 2050 compared to 2018. Although, the percentage changes of the seven indicators go to the same direction for both diet scenarios, the largest differences can be observed in the change in diet affordability, fertilizer use and GHG emissions. In particular the diet affordability of the lowest income class improved more in the FLX diet scenario. Between 2018 and 2050 there is a strong increase in fertilizer use in the FLX diet and around six times higher compared to the HIC diet. In contract, GHG emissions is around two and an half times higher compared to the FLX diet. In the next sections each indicator will further analyses to explain the differences between the diet scenarios.

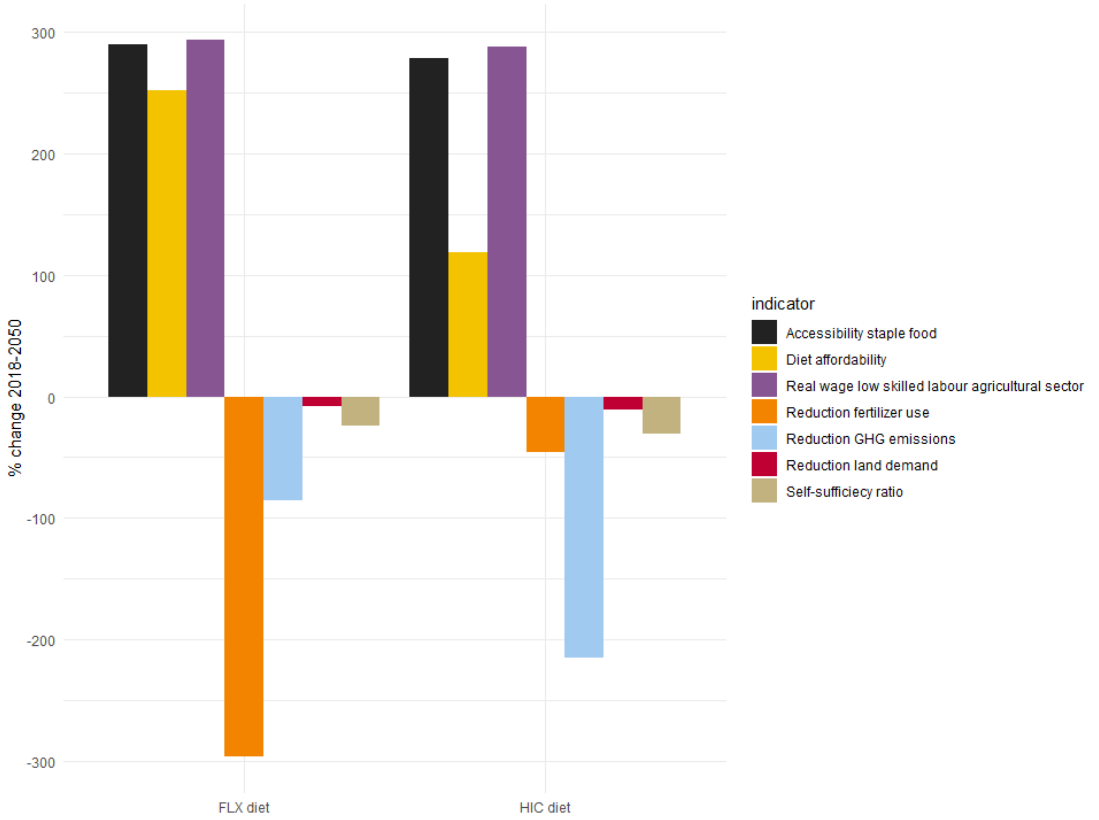

Figure 1: Trade-offs between the flexitarian and high income diet

Wages, diet affordability and total household spending

In both scenarios, the wages of the five occupation types agricultural low skilled, services and shop, clerks, technicians and other specialist, and officials and managers are increasing in the agricultural and non-agricultural sectors (figure 2). Except of the agricultural low skilled labour, the increase in wages are higher for the HIC diet scenario compared to the FLX diet scenario. In addition the average increase on household expenditures on food and non-food commodities are also higher for the HIC diet scenario, namely 583% and 296% on food and non-food compared to 353% and 263.4 %. The strong differences in the expenditures on food can be explained by the higher purchasing cost of the HIC diet. Looking at the real price index (figure 3) there can be observed that in particular under HIC diet scenario the price of meat and to a lower extent the price of dairy (strongly) increased between 2018 and 2050 which contributes significantly to the HIC diet. In contrast, the price increase under the FLX is especially for nuts and seeds, fruits, and vegetables. The average price increase on non-food items is higher for the HIC diet scenario. As a result, this partly offset increase in wages for the HIC diet scenario. As a result, the diet affordability for AgOthLs and ServShop in the non-food sector is decreasing with 41% and 15% respectively, and in general the affordability on the diets and non-food consumption is higher for the lowest income classes under the FLX diet scenario.

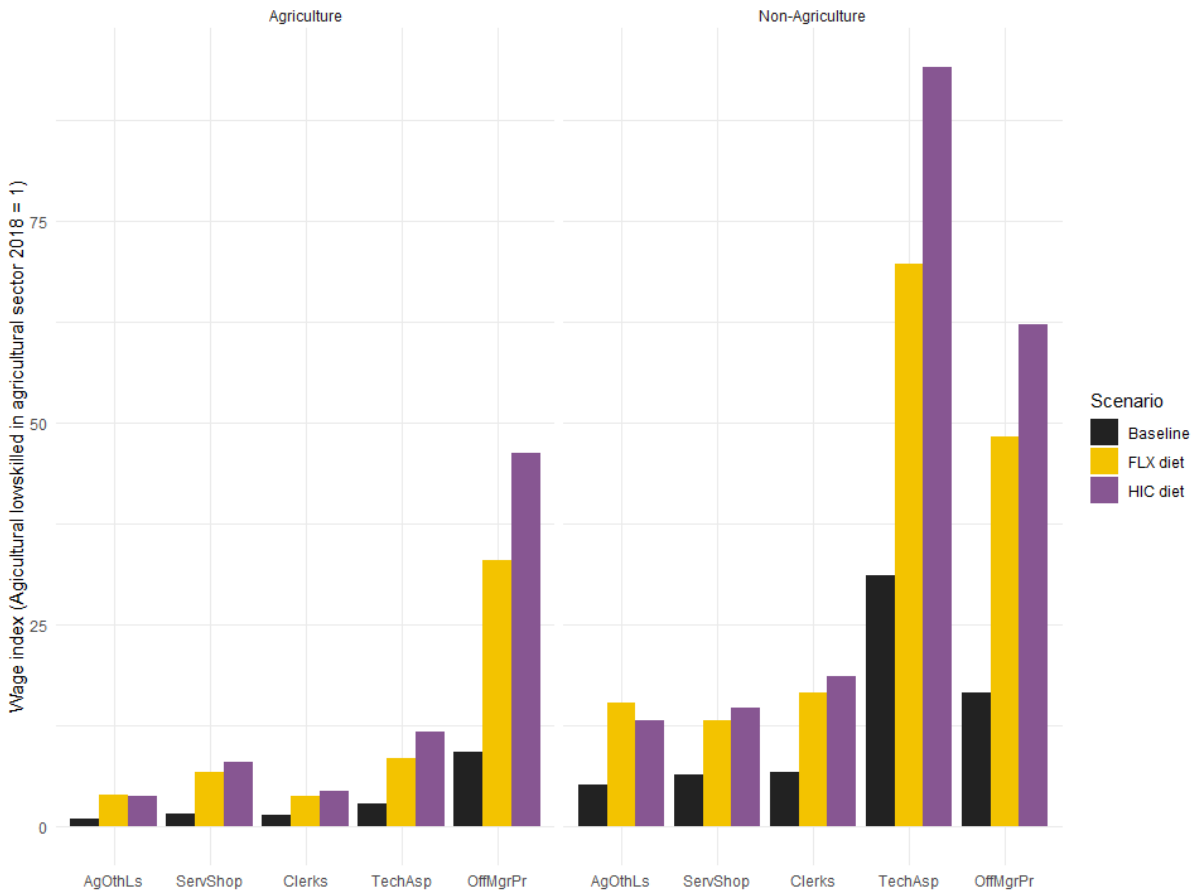

Figure 2: Wage index (agricultural low skilled employers in agricultural sector 2018 = 1) of the net real wage for the five occupation types agricultural low skilled (agOthLs), services and shop (ServShop), clerks, technicians and other specialist (TechAsp), and officials and managers (OffMgrPr) are in the agricultural and non-agricultural sectors

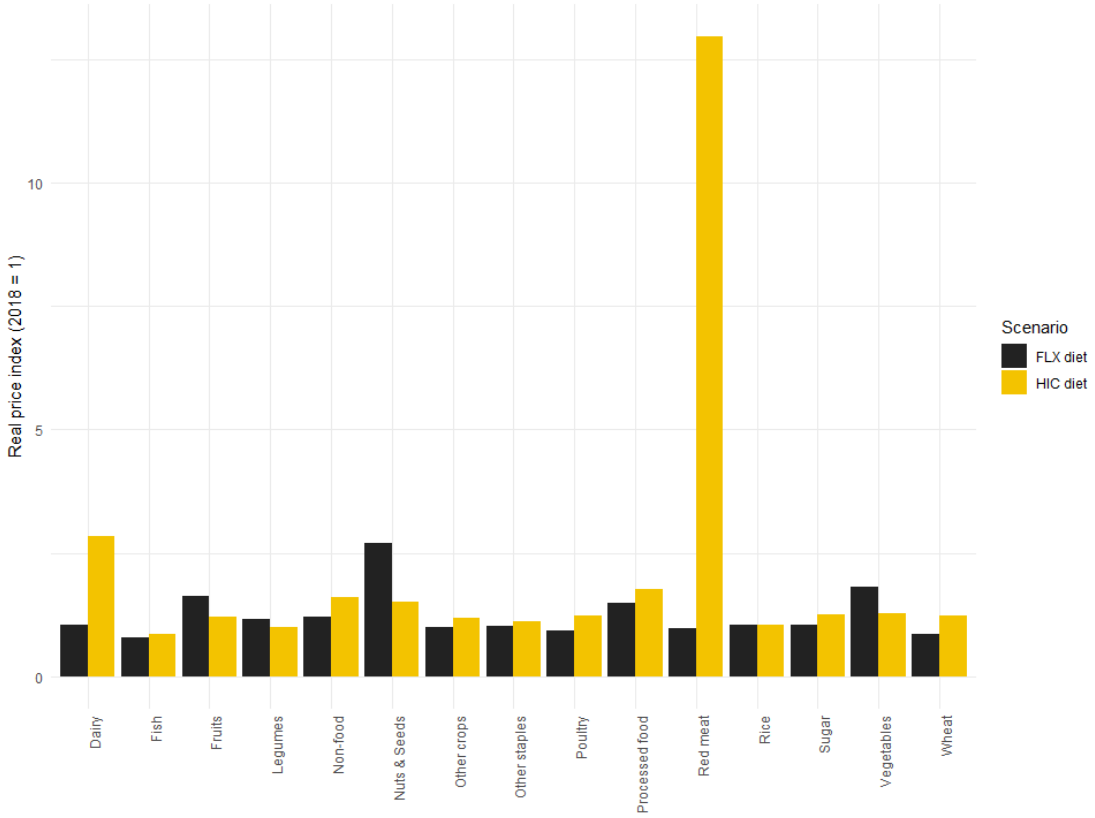

Figure 3: Real price index of the private household real basic price (2018 = 1)

Production and trade

Strong differences in the change in the volume of production and trade between 2018 and 2050 can be observed between the FLX and the HIC diet scenarios (figure 4). The strongest growth in production is in the production of nuts and seeds (with a small production volume in 2018) for the flexitarian diet followed by the production of vegetables. For the HIC diet scenario the strongest growth is in the poultry and red meat sector which growths in both cases by more then 1000%. In both scenarios, the only decrease in production can be found for rice and aquaculture, the two biggest agricultural sectors. The production volume of processed food is increasing in both scenarios, but the growth is around one-third higher for the HIC diet scenario. To meet the nuts and seeds demand for the FLX and the read meat demand for the HIC diet scenario, imports are increasing by more the 40000% and 30000% repressively. Another major increase of imports are for other staples for the HIC diet scenario with more then 5000%. The biggest increase of exports is for non-food items with an increase of around 450% and 370%. In terms of the value of net export (see table 1), Bangladesh with become a net exporter in 2050 in both scenarios, with an trade deficit in food and a trade surplus for non-food items.

Table 1: Net export in value for base year 2018 and the FLX and HIC scenario in 2050

Base year (2018)		**FLX (2050)**		**HIC (2050)**	
Food	-4995.1	Food	-60767.9	Food	-31698.3
Non-food	-3994.2	Non-food	68061.9	Non-food	58309.5
Total	-8989.3	Total	7294	Total	26611.2

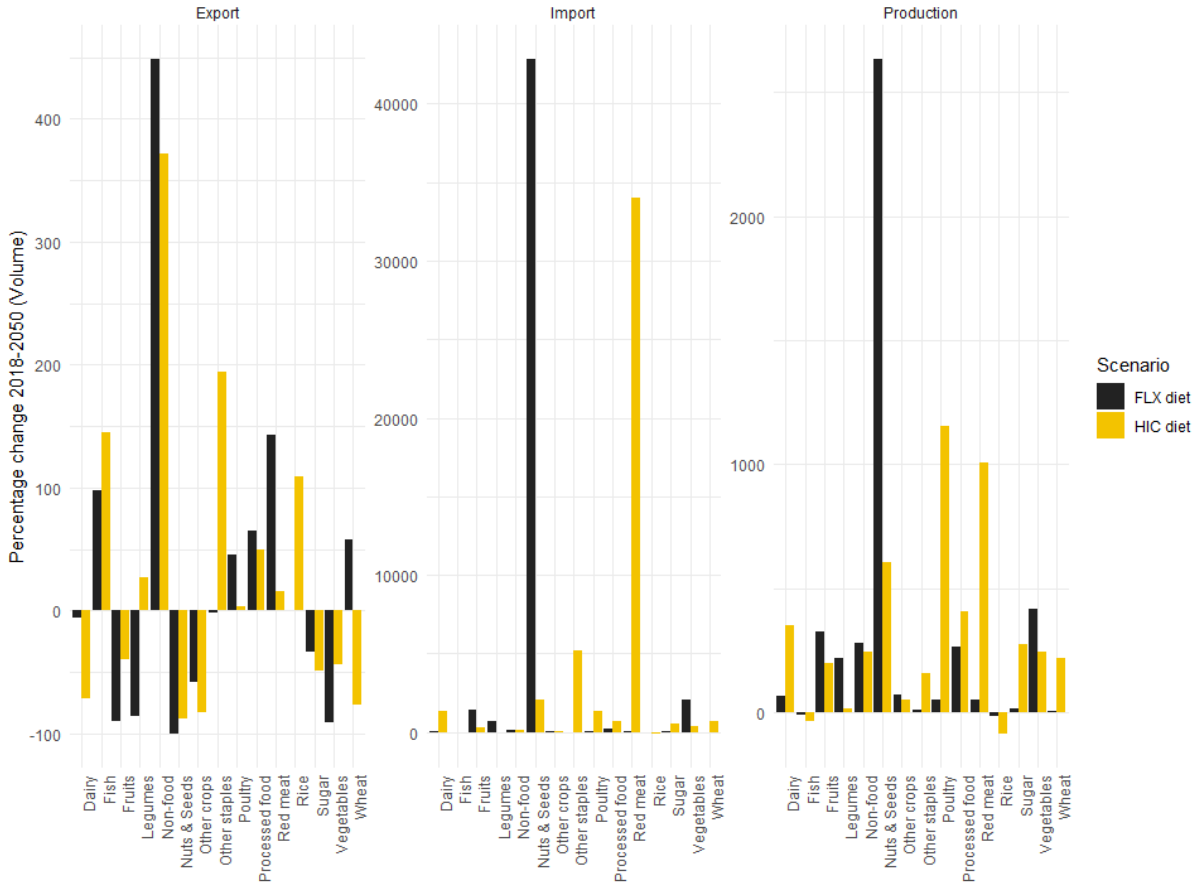

Figure 4: Percentage change between 2018 and 2050 of the volume in production, import and export

Land demand

In both diet scenarios there is an increase in land demand between 2018 and 2050. In 2018, 86.4% of the total available land sustainable for agriculture was cultivated and increased to 93.6% and 95.6% in 2050 for the FLX and HIC respectively. The lion's share of the total land demand is for rice production in the base year and in 2050 for both scenarios (figure 5). However, driven by the change in consumption and expected from the change in domestic production described in the previous section, the land demand for rice production is decreasing in both diet scenarios and more than twice as high for the HIC diet and substituted for other crops. In the FLX diet scenarios, the largest increase in land demand is for nuts and seeds production followed by the demand for vegetable production. For the HIC diet scenarios, the increase is land demand is for the production of red meat (grassland for cattle), non-food and diary.

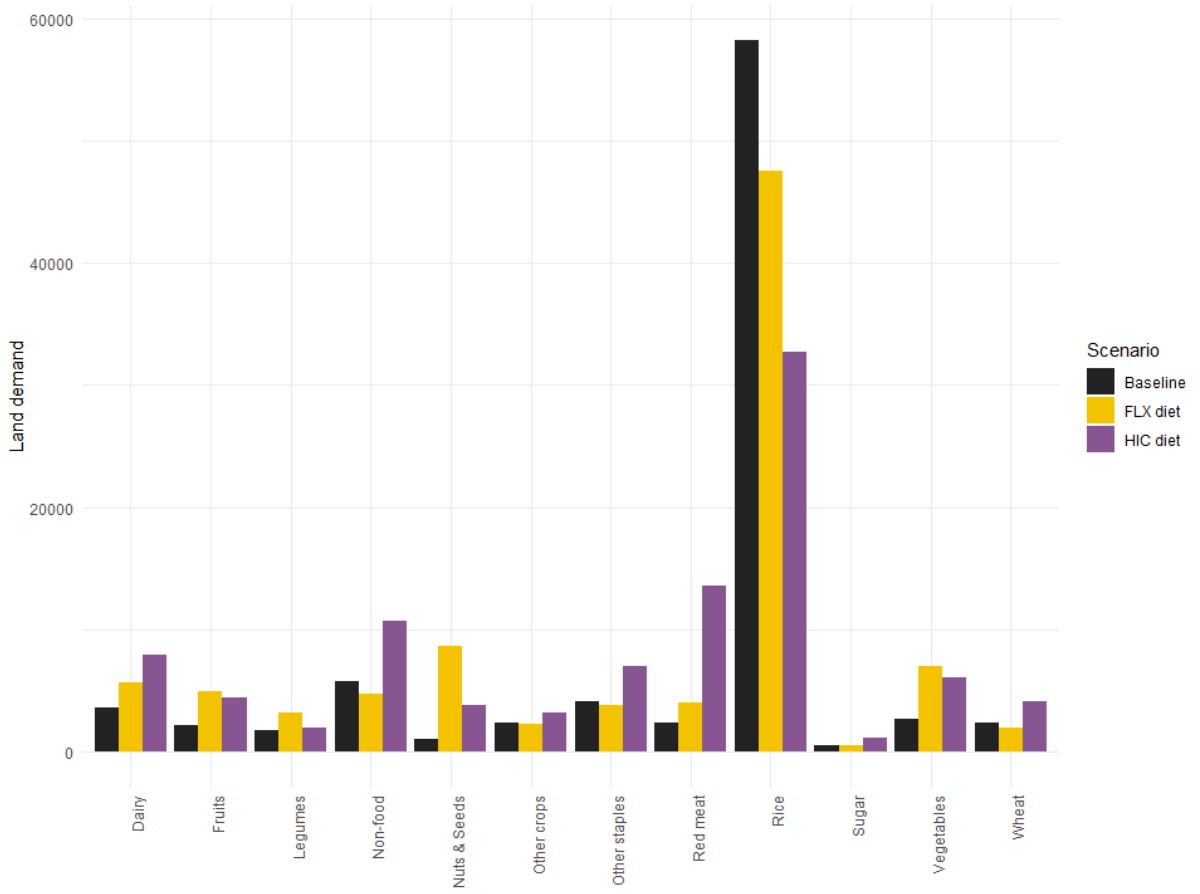

Figure 5: Land demand

Environmental effects

As earlier described, the increase in total GHG emissions between 2018 and 2050 is around two and an half times higher in the HIC diet scenario compared to the FLX diet. This is the result of the strong increase in domestic production of red meat in the HIC diet scenario resulting in an increase of 480% in total food production, compared to 142% for the FLX diet. As a result of a higher production of non-food commodities in the FLX diet scenario compared to the HIC diet in 2050, the emissions in the FLX diet scenario are increasing with 227% between 2018 and 2050 compared to 181% for the HIC diet scenario.

The around six times higher increase of fertilizer use between 2018 and 2050 in the FLX diet scenario compared to the HIC diet scenario is the result of the increase in domestic production of nuts and seeds, contributes to around 50% of total fertilizer use, and to a lower extent vegetables.

Discussion

In current model setup only the diets for Bangladesh are shocked. Under a scenario in which all countries moves to a Flexitarian or high income country, demand will change dramatically, so as a result food production, trade patterns and food prices.

Conclusion

In this study we compared different diet scenarios, the EAT Lancet flexitarian diet scenario modified for Bangladesh with a high share of vegetables, fruits, nuts and needs, and legumes, and a low share of red meat, dairy and poultry and a high income diet with a high share of red meat dairy and poultry, and a higher demand for wheat and other staples compared to the flexitarian diet. The results shows that future consumer choices on food consumption in Bangladesh will have major impact on overall economy of Bangladesh, socio-economic indicators and the environment. As a result of a strong increase in red meat and dairy in the HIC diet scenario, the diet in this scenario becomes more expensive compared to the average diet in the FLX diet scenario. In addition, although the increase in wages of low skilled labour (agricultural workers and other low skilled workers, and services and shop workers) is in not all cases higher in the FLX diet scenario, the purchasing power for this occupation category is higher as a result of lower increase in prices of the FLX diet as well the average price of non-food commodities compared to the HIC diet scenario. In contrast, this is not the case for the high skilled labour for which the increase in purchasing power is higher for the HIC diet scenario. These results indicates that the poverty reduction is higher and the inequality lower in the FLX diet scenario. As a result of a higher demand for non-food, GHG emissions are higher in the non-food sector in the FLX diet scenario compared to the HIC diet scenario. However, the total GHG in the HIC diet scenario is higher driven by the strong increase of red meat consumption. Fertilizer use in the FLX diet scenario is around six times higher compared to the HIC diet scenario as a result of the strong increase in the production of nuts and seeds and to a lower extent vegetable production.

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