

AGEDI | THE ABU DHABI GLOBAL ENVIRONMENTAL DATA INITIATIVE
CLIMATE CHANGE PROGRAMME
SOCIOECONOMIC SYSTEMS: FOOD SECURITY

Atmospheric
Modelling

Arabian Gulf
Modelling

Terrestrial
Ecosystems

Marine
Ecosystems

Transboundary
Groundwater

Water Resource
Management

Al Ain Water
Resources

Coastal Vulnerability
Index

Desalinated
Water Supply

Food Security

Public Health Benefits
of GHG Mitigation

Sea Level Rise

Suggested Citation: AGEDI. 2015. Food Security and Climate Change. LNRCCP. CCRG

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About this Final Technical Report

In October 2013, the Environment Agency of Abu Dhabi launched the "Local, National, and Regional Climate Change (LNRCC) Programme to build upon, expand, and deepen understanding of vulnerability to the impacts of climate change as well as to identify practical adaptive responses at local (Abu Dhabi), national (UAE), and regional (Arabian Peninsula) levels. The design of the Programme was stakeholder-driven, incorporating the perspectives of over 100 local, national, and regional stakeholders in shaping 12 research sub-projects across 5 strategic themes.¹ The "Food Security & Climate Change" sub-project within this Programme aims to assess the impact of climate change on the long-term food security of the UAE, while also seeking to identify and evaluate potential adaptation measures that can reduce future climate change-related risks such as declining agricultural productivity in food-exporting countries, tightening world food markets, and recurrent food price spikes.

The purpose of this "Final Technical Report" is to offer a summary of what has been learned in carrying out the research activities involved in the "Food Security & Climate Change" sub-project. This report seeks to provide the reader with an overall sense of the methodological approach, analytical framework, data acquisition challenges, key findings, and other issues that can support future policymaking regarding the strengthening of food security strategies. Ultimately, this "Final Technical Report" report seeks to provide a useful synthesis of all research activities that offers partners and stakeholders a basis upon which to account for the potentially growing risks to food imports under climate change and the impacts of such risks on vulnerable populations within the UAE.

The authors of this report are Bill Dougherty (Principal Investigator) from the Climate Change Research Group and Patrick Keys from Colorado State University. The authors would like to acknowledge the significant contributions of several colleagues: Clemens Breisinger, Siwa Msangi, and Daniel Mason-D'Croz from the International Food Policy Research Institute (IFPRI), Eckart Woertz from the Barcelona Centre for International Affairs (CIDOB), and Ian Tellam from Adaptify

¹ For more information on the LNRCC programme and the food security sub-project, please contact Jane Glavan (jglavan@ead.ae).

Acknowledgments

Many individuals provided invaluable support, guidance, and input to the National Food Security and Climate Change project.

The authors would like to express their sincere and heartfelt expressions of gratitude for their review by providing comments, feedback, data and/or the opportunity to present multiple deliverables within the project process including:

- Dr. Abdul-Majeid Haddad, United Nations Environment Programme, Regional Office for West Asia (UNEP-ROWA)
- Ms. Eva Torreblanca, Environment Agency – Abu Dhabi (EAD)
- Dr. Frederic Launay, Environment Agency – Abu Dhabi (EAD)
- Dr. Holger Hoff, Stockholm Environment Institute (SEI)
- Mr. Hossam Al Alkamy, Environment Agency – Abu Dhabi (EAD)
- Mr. Khaled Sokhny, Prime Minister's Office (PMO)
- Mr. Kim Chance, Abu Dhabi Food Control Authority (ADFCA)
- Dr. Majid Al Qassimi, Ministry of Climate Change and Environment (MOCCAEC)
- Ms. Mari Luomi, Emirates Diplomatic Academy (EDA)
- Ms. Maria Cordeiro, Environment Agency – Abu Dhabi (EAD)
- Ms. Nadia Rouchdy, Emirates Wildlife Society (EWS) – WWF
- Ms. Naoko Kubo, Ministry of Climate Change and Environment (MOCCAEC)
- Dr. Richard John Obrien Perry, Environment Agency – Abu Dhabi (EAD)
- Mr. Sameer Asaf, Ministry of Climate Change and Environment (MOCCAEC)
- Dr. Simon Pearson, Environment Agency – Abu Dhabi (EAD)

A very special thank-you to the Food Security Committee of the Ministry of Climate Change and Environment for allowing us to share our results and experience. We wish you the best in your planning.

We are additionally thankful the participation, time and effort that multiple stakeholders across the region who participated in the multitude of meetings and dialogue. The authors would like to especially thank the following stakeholders for their particularly involved participation: Abdullah Salem Eisaei SCAD, Alessandro Galli Global Footprint Network, Amal Aldababseh MASDAR Institute, Andrew Gauldie FAO, Bart Hilhorst Dutch Government on international land investments, David Currie FAO, Eihab Fathelrahman College of Food and Agriculture, Environment Agency - Abu Dhabi (EAD) team, Fahed Al Hammadi MOCCAEC, Jin Young Kim GGGI, Marouane Temimi MASDAR Institute, Mohammed Angawi GGGI, Piio Tomaso Perri RECOFI, Sameh Raafat Abdel Hamid SCAD, Shaima Aydarous MOCCAEC, Tanzeed Alam EWS-WWF.

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List of Acronyms

AED	UAE dirhams
AGEDI	Abu Dhabi Global Environmental Data Initiative
cap	capita
CCRG	Climate Change Research Group
CPI	Consumer price index
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EAD	Environment Agency of Abu Dhabi
EFSeCC	<u>E</u> mirates <u>F</u> ood <u>S</u> ecurity under <u>C</u> limate <u>C</u> hange
EI	Euromonitor International
FAO	Food and Agricultural Organization of the United Nations
FPU	Food Producing Units
IFPRI	International Food Policy Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade model
GCM	Global Circulation Model
GDP	Gross domestic product
GHG	Greenhouse gas
ha	hectare
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
Kg	kilograms
LNRCCP	Local, National, and Regional Climate Change Programme
Mt	metric tonnes
NSB	National Bureau of Statistics (UAE)
PC	personal computer
SCAD	Statistical Centre of Abu Dhabi
SRES	Special Report on Emissions Scenarios
UN	United Nations
UAE	United Arab Emirates
USDA	United States Department of Agriculture
WB	World Bank
WEO	World Economic Outlook

Executive Summary

The UAE is a country that is heavily dependent on food imports and may be vulnerable to food supply constraints and associated price shocks associated with climate change impacts in food-exporting countries. The combination of climate change-induced declining agricultural productivity in food-exporting countries, tightening of world food markets, and price speculation pressures could lead to several adverse circumstances in the UAE. These may include recurrent retail food price spikes and/or a need for substantial food subsidies. Households throughout the seven emirates that have annual incomes at the lower end of the national range could find themselves in a position where they would be subject to spending a growing share of limited household budgets for food.

This study focused on the potential risks to the UAE's long-term food security under the adverse impacts of climate change. The recent global food crisis of 2008, with its price spikes and subsequent social unrest in several countries, represents an important challenge to the development of food security plans capable of producing human well-being and social harmony. Even without the additional threat posed by climate change, the global food crisis exposed interlinked vulnerabilities associated with agricultural productivity, international food trade markets, and food commodity prices. With climate change, current challenges of soil destruction, inadequate water supply, and stagnant mono-cultured crop yields will likely be seriously exacerbated, leading to reduced crop productivity in food-exporting countries, steady increases in food prices, and increased food insecurity around the world.

The overall goal of this study was to quantify the impact of climate change on long-term food security in the UAE on two levels. First, the study focused on the “Macro” or national level. This portion of the assessment addressed the interconnected issues of international food trade flows/constraints, and climate change impacts on agricultural productivity of food exporting countries. Second, the study focused on the “Micro” or household level. This portion of the assessment addressed the economic vulnerability of UAE households to food price volatility resulting from the impact of macro-level considerations.

The analytical framework for the macro- and micro-level assessments were codified into a food security risk software program. This was done in order to make accessible both the actual results of food security analysis, as well as offer the capability to interested stakeholders to conduct subsequent analyses. To this end, a model was developed – the Emirates Food Security under Climate Change model (EFSeCC) – incorporating all the data assumptions, modeling techniques, and vulnerability index calculations. The tool is a macro-driven Graphical User Interface (GUI) built in Excel software that implements the sequence of analytical steps in the modeling framework. The tool also offers users a way to visualize results and explore alternative scenarios of food supply and household vulnerability to food price impacts.

At the macro level, a Food Insecurity Index was calculated for each imported food item to the UAE, as well as for each major food exporter country to the UAE. The index accounts for a broad range of potential climate change scenarios that could affect global food trade flows. The basis for constructing the food insecurity index for food items and major exporter countries is the cumulative food import gap projected under conditions of climate change.

The Index ranges from 1 to 10, with 1 representing strongly secure and 10 representing strongly insecure.

Table ES-1 provides a summary of results. Green-shaded rows indicate high food import security under climate change (Index =1 to 2). Light red-shaded rows indicate increasing levels of food import insecurity under climate change countries (Index = 5 to 10, where 10 indicates the highest level of food import insecurity). Light brown-shaded rows indicate the middle range of food import insecurity (Index =3 to 4).

Table ES-1: Food Insecurity Index results

a) By food item

Food item	Food import status	Food Security index
BEEF (i.e., Bovine Meat)	UNCONSTRAINED	1
CASS (i.e., Cassava and	CONSTRAINED	6
CHKP (i.e., Pulses, and	PARTIALLY CONSTRAINED	3
EGGS (i.e., Eggs)	PARTIALLY CONSTRAINED	2
GRND (i.e., Groundnuts	CONSTRAINED	6
LAMB (i.e., Mutton & Goat	UNCONSTRAINED	1
MAIZ (i.e., Maize and	UNCONSTRAINED	1
MILK (i.e., Milk - Excluding	PARTIALLY CONSTRAINED	3
MILL (i.e., Millet and	CONSTRAINED	6
OGRN (i.e., Barley and	CONSTRAINED	6
PKOL (i.e., Oil - Palm and	PARTIALLY CONSTRAINED	3
PORK (i.e., Pigmeat)	CONSTRAINED	6
POTA (i.e., Potatoes and	PARTIALLY CONSTRAINED	5
POUL (i.e., Poultry Meat)	PARTIALLY CONSTRAINED	3
RICE (i.e., Rice (Milled	CONSTRAINED	10
RPOL (i.e., Rape and	CONSTRAINED	6
RPSD (i.e., Rape and	CONSTRAINED	6
SBOL (i.e., Soyabean Oil)	CONSTRAINED	6
SFOL (i.e., Sunflowerseed	CONSTRAINED	6
SNFL (i.e., Sunflower seed)	CONSTRAINED	6
SOYB (i.e., Soybeans)	CONSTRAINED	7
SUBF (i.e., Fruit -	CONSTRAINED	8
SUGC (i.e., Sugar (raw))	PARTIALLY CONSTRAINED	2
SUGR (i.e., Sugar (Refined))	CONSTRAINED	7
SWPY (i.e., Sweet potatoes)	CONSTRAINED	6
TEMF (i.e., Fruit -	CONSTRAINED	7
TOOL (i.e., Oil - Other)	CONSTRAINED	4
VEGE (i.e., Vegetables - All)	CONSTRAINED	8
WHEA (i.e., Wheat and	CONSTRAINED	10

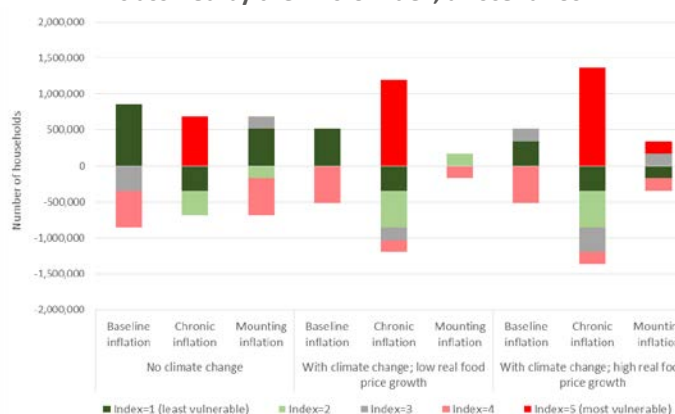
b) by country

Country name	Criterion		Food Security index
	Share of Imports	Climate change impact	
Argentina	4	2	3
Australia	4	2	3
Brazil	7	3	5
Canada	2	1	2
China	2	3	3
Egypt	1	3	2
Ethiopia	1	2	2
France	1	3	2
Germany	2	5	4
Gulf countries	2	2	2
India	9	3	6
Indonesia	1	4	3
Iran (Islamic Republic of)	3	8	6
Jordan	2	2	2
Lebanon	1	2	2
Malaysia	2	4	3
Netherlands	2	2	2
New Zealand	1	2	2
Pakistan	3	4	4
Paraguay	2	3	3
Philippines	2	5	4
South Africa	2	10	6
Spain	1	2	2
Thailand	2	4	3
Ukraine	2	2	2
United States of America	2	4	3
All other countries	10	3	7

In short, most food imports to the UAE will be constrained under climate change. Rice and wheat are strongly insecure food items for the UAE under climate change. On the other hand, beef, lamb meat, and maize are strongly food secure items suggesting that current food trade flows will not be adversely affected in the future. Regarding exporting countries, imports from Brazil, India, Iran, and South Africa are projected to be constrained with climate change. On the other hand, tradition exports such as Pakistan, Germany, and Thailand are strongly food secure countries suggesting that current food trade flows from these countries will not be adversely affected in the future.

At the micro-level, a Food Insecurity Index was calculated for each household decile for the range of scenarios. The basis for constructing the micro-level food insecurity index was the extent to which the share of household food expenditures exceed a certain level considered to be a plausible characterization of a food secure situation at the household level. In this study, 17% was assumed to be the expenditure share that separated food secure households from those that are less secure. The impact of

Table ES-2: Change in the total number of UAE households classified by the Micro Index, all scenarios



climate change on household food security is illustrated in Figure ES-2. This figure shows that climate change will lead to serious shifts in food spending patterns, In particular, introducing climate change increases the number of the most vulnerable households (i.e., red bars) from 685 thousand to 1.2 million (i.e., 75% increase) in a low real food price scenario and to 1.4 million (i.e., 100% increase) in a high real food price scenario.

Introduction

The UAE is a country that is heavily dependent on food imports and may be vulnerable to food supply constraints and associated price shocks associated with climate change impacts in food-exporting countries. The combination of climate change-induced declining agricultural productivity in food-exporting countries, tightening of world food markets, and price speculation pressures could lead to several adverse circumstances in the UAE. These may include recurrent retail food price spikes and/or a need for substantial food subsidies. Households throughout the seven emirates that have annual incomes at the lower end of the national range could find themselves in a position where they would be subject to spending a growing share of limited household budgets for food.

This study focused on the potential risks to the UAE's long-term food security under the adverse impacts of climate change. The recent global food crisis of 2008, with its price spikes and subsequent social unrest in several countries, represents an important challenge to the development of food security plans capable of producing human well-being and social harmony. Even without the additional threat posed by climate change, the global food crisis exposed interlinked vulnerabilities associated with agricultural productivity, international food trade markets, and food commodity prices. With climate change, current challenges of soil destruction, inadequate water supply, and stagnant mono-cultured crop yields will likely be seriously exacerbated, leading to reduced crop productivity in food-exporting countries, steady increases in food prices, and increased food insecurity around the world.

Hence, the aim of this study was to quantify the impact of climate change on long-term food security in the UAE.² The analysis focused on an integrated assessment that sought to address the interconnected issues of international food trade flows/constraints, climate change impacts on agricultural productivity of food exporting countries, and economic vulnerability of UAE households to food price volatility. Data inputs and scenario-driven results have been codified into an analytical tool called the “Emirates Food Security under Climate Change” model” or EFSeCC, which offers a way to visualize results and explore alternative scenarios of food supply and household vulnerability to food price impacts.

Section 2 provides an overview of the context for the study, including a characterization of the UAE's food security situation as inferred from international standards. Section 3 reviews the methodological approach applied in the study and addresses goals/objectives, major analytical steps, modeling framework, among other topics. Section 4 addresses historical patterns of food imports to the UAE. Section 5 describes the IMPACT model and structure of its outputs for productivity, prices and other parameters. Section 6 focuses on household income and spending patterns in the UAE and includes a summary of a number of socioeconomic characteristics pertinent to the development of an assessment of household-level vulnerability to climate change. Sections

² This Final Technical Report is a summary of methods and overall results. It builds upon previous technical reports prepared as part of the "Food Security and Climate Change" sub-project. These reports include the "Preliminary Findings Report", the "Draft Visualizations Report", and the "Draft Technical Report". The reader is kindly referred to those reports for quantitative details regarding specific assumptions (e.g., agricultural productivity in food exporting countries, projected food import quantities, etc) as well as the structure of the EFSeCC model.

7 and 8 provide a summary of the approach to macro-level and micro-level modeling, respectively. Finally, Section 9 presents the approach to the development of vulnerability indicators for the macro- and micro level portions of the study and provide the core conclusions of the study.

1. Background

This section provides a synthesis of the methods for evaluating the UAE's food security under climate change. The section begins with a brief overview of the context of the study, with a focus on the concept of food security, international food trade, and the links between food prices and climate change links. The section concludes with a review of food policies currently in place or under consideration in the UAE and a brief summary of the framework for developing food security indicators for the UAE.

1.1. Food security context

Food security is a broad and multifaceted issue that is interconnected with many economic, social, political and health-related concerns (EIU, 2014). The concept of food security is typically defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences (FAO, 2006). The Food and Agriculture Organization FAO defines food security as a *"situation [...] when all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO, 2006). Hence, food security is not narrowly defined as whether sufficient amounts of food can be produced locally, but whether the monetary and non-monetary resources at the disposal of the population are sufficient to allow everyone access to adequate quantities and qualities of food (Ludi, 2009). At a national level, food security exists when all of a country's citizens are individually food secure.

The FAO further defines food security as dependent on four key dimensions: food availability, food access, nutritional status, and stability of food supplies. These are briefly described in the bullets below (text is quoted from FAO, 2006). The FAO has developed a time-series database (i.e., FAOSTAT) that provides annual data at the country and regional level for indicators across the four major food security dimensions described below.

- **Food availability:** The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid).
- **Food access:** Access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet.
- **Utilization:** Utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. This brings out the importance of non-food inputs in food security.
- **Stability:** To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability can therefore refer to both the availability and access dimensions of food security.

One way to frame the UAE's current food security context is to conduct a comparative

analysis. This offers a point of the departure for establishing a baseline characterization of the level of food security in the UAE compared to other countries. To do this, FAO's food security indicator databases for the period 1991 to 2015 were evaluated to compare the UAE to other countries, namely "developed" countries, where food security is typically good, and the world at large. Specifically, there are 32 indicators that the FAO uses to characterize the above four dimensions of food security at the national level, as summarized in Table 4-1.

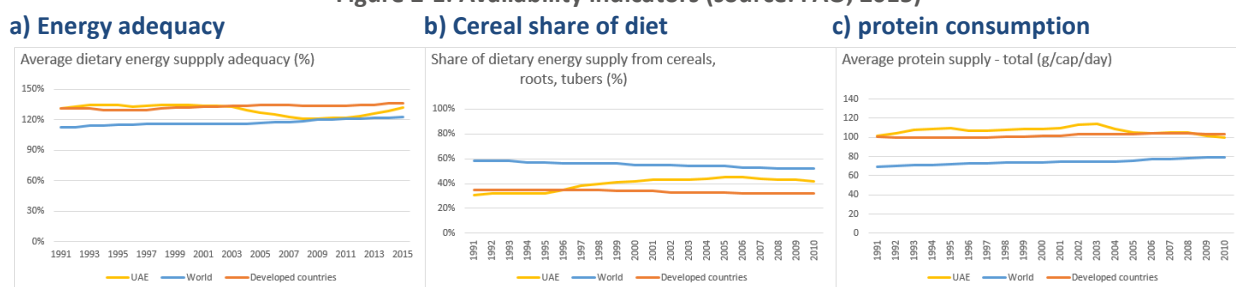
For some of the FAO indicators of food security, there are incomplete data. For other indicators, the information is not particularly relevant to the national circumstances of the UAE. Nevertheless, there are complete time-series data for ten (10) indicators that were considered highly relevant for characterizing UAE food security, at least on a

Table 2-1: Food security dimensions & indicators (FAO, 2015)

Food security dimension	Indicator
Availability	1. Average dietary energy supply adequacy (%) (3-year average)
	2. Share of dietary energy supply derived from cereals, roots and tubers (%) (3-year average)
	3. Average value of food production (constant US per person) (3-year average)
	4. Average protein supply (g/capita/day) (3-year average)
	5. Average supply of protein of animal origin (g/capita/day) (3-year average)
Access	6. Prevalence of undernourishment (%) (3-year average)
	7. Percentage of paved roads over total roads (%)
	8. Share of food expenditure of the poor (%)
	9. Prevalence of food inadequacy (%) (3-year average)
	10. Rail-lines density (per 100 square km of land area)
	11. Road density (per 100 square km of land area)
	12. Domestic food price index (index)
	13. Gross domestic product per capita, PPP (constant 2011 international \$)
	14. Depth of the food deficit (kcal/capita/day) (3-year average)
	15. Number of people undernourished (per 100,000) (3-year average)
Utilization	16. Access to improved water sources (%)
	17. Access to improved sanitation facilities (%)
	18. Percentage of children under 5 years of age who are stunted (%)
	19. Percentage of children under 5 years of age affected by wasting (%)
	20. Percentage of children under 5 years of age who are underweight (%)
	21. Percentage of adults who are underweight (%)
	22. Prevalence of anaemia among children under 5 years of age (%)
	23. Prevalence of vitamin A deficiency in the population (%)
	24. Prevalence of iodine deficiency (%)
	25. Prevalence of anemia among pregnant women (%)
Stability	26. Value of food imports over total merchandise exports (%) (3-year average)
	27. Percentage of arable land equipped for irrigation (%) (3-year average)
	28. Cereal import dependency ratio (%) (3-year average)
	29. Domestic food price volatility (index)
	30. Political stability and absence of violence/terrorism (index)
	31. Per capita food production variability (US per person constant 2004-06)
	32. Per capita food supply variability (kcal/capita/day)

comparative basis relative to other countries. These are shown in bolded font in Table 2-1. At least two indicators were evaluated for each of the four major dimensions of food security.

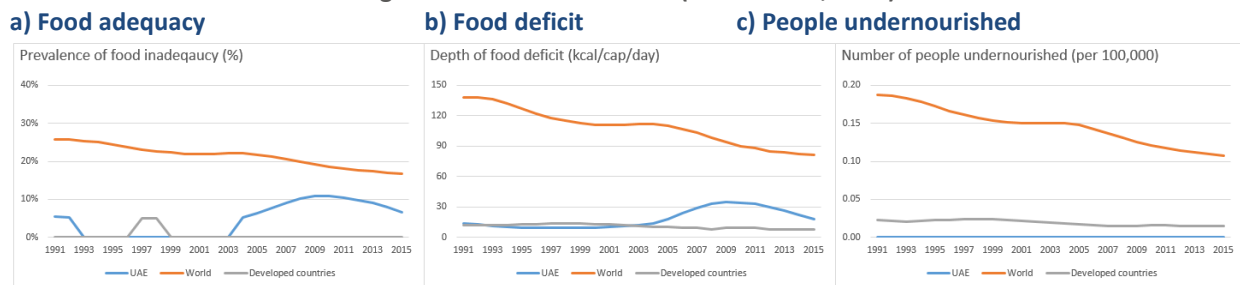
Figure 2-1: Availability indicators (source: FAO, 2015)



While not exhaustive, these indicators are adequate for establishing a foundational narrative of baseline food security in the UAE. The subsections that follow offer a summary of the results of these comparisons.

Food availability refers to availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid). Figure 2-1 shows average food availability for three indicators, namely energy adequacy, cereal share in the overall diet, and per capita protein consumption for the period 1991-2010. As can be seen in these Figures, food availability in the UAE is more closely aligned with developed countries,

Figure 2-3: Access indicators (source: FAO, 2015)

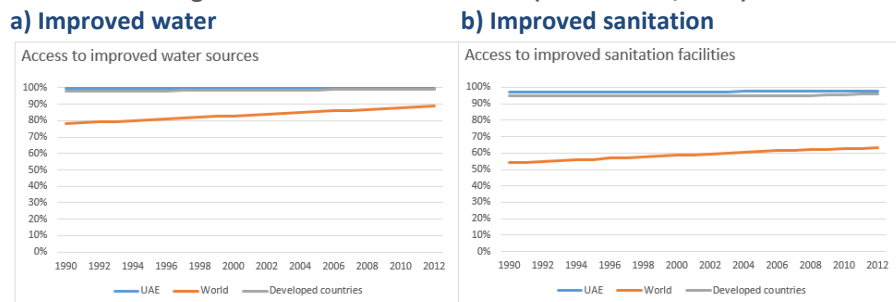


typically acknowledged as being more food secure. This is most evident regarding protein consumption where per capita consumption exceeded developed country intake for much of the period. Notably, the energy adequacy of UAE diets dipped during the period just after the food crises of 2008, but has shown a return to developed country levels. Since 1997, the cereal share of diets in the UAE has risen to higher levels though is showing a convergence to developed country levels in recent years. The broad conclusion derived from these data is that the UAE population is relatively food secure as measured by this subset of food availability indicators.

Food access refers to access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet. This encompasses a set of wide ranging features like the level of road infrastructure (for accessing food markets), level of poverty (indicating a lack of access to food markets), the existence of government safety nets (to compensate for a lack of access to food markets), among others. Figure 2-2 shows average food access for three indicators, namely, food adequacy, food deficit, and the under-nourished population for the period 1991-2015. For both food adequacy and food deficit, the UAE shows levels near or better than developed countries for the period before the food price crisis. In recent years, both of these indicators have been trending toward developed country levels. For the people under-nourished indicator, the FAO reports zero levels throughout the period for the UAE. This trend is better by far than world under-nourished population levels and even those levels prevailing in developed countries. The broad conclusion derived from these data is that the UAE population is relatively food secure as measured by this subset of food access indicators.

Food utilization refers to the utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. This encompasses a set of non-food inputs in food security such as sanitation, water resources, and vitamins. For all of the indicators regarding the prevalence of nutrition-related

Figure 2-2: Utilization indicators (source: FAO, 2015)



problems in children, the FAO reports zero prevalence in the UAE, consistent with levels in developed countries. Figure 2-3 shows average food utilization for two indicators, namely, access to improved water and sanitation for the period 1991-2012. For both of these indicators, the UAE hovers near full access at around 100%. The broad conclusion derived from these data is that the UAE population is relatively food secure as measured by this subset of food utilization indicators.

Food stability refers the extent to which country circumstances enable people to be able to withstand a range of potential shocks. That is, to be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of

sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). Hence, the concept of stability incorporates both the availability and access dimensions of food security described in previous subsections. Figure 2-4 shows average food stability for two indicators, namely, cereal import dependency and the import-export ratio for the period 1991-2010. The UAE deviates sharply from both developed countries and the world at large for cereal imports. This has been discussed in previous sections of this report and is understood to be at the core of national food security debates. Notably, the ratio of the value of total food imports to total exports of goods is quite low, less than 5% for most of the period which is even lower than developed countries. This implies a high degrees of food stability. The broad conclusion derived from these data is that the UAE population is relatively food secure as measured by this subset of food stability indicators.

Taken together, the comparisons discussed above suggest that UAE current food security is high, on the order of the food security situation in developed countries. This, in fact, is the same conclusion reached by a number of other frameworks. For example, the Integrated Food Security Phase Classification (IPC) is a standardized scale developed by the FAO's Food Security Analysis Unit (FSAU), the index integrates food security, nutrition and livelihood information into a statement about the nature and severity of a crisis and implications for strategic response. Countries are defined as food secure if more than 80% of households can meet their food needs without resorting to atypical coping strategies (see Table 2-2). The UAE is classified in the highest food security category (i.e., "Generally Food Secure") in this classification system.

Another example is the Global Food Security Index (GFSI), commissioned by the DuPont Company and developed by the Economist Intelligence Unit (EIU). The GSFI measures the

Table 2-2: Integrated Food Security Phase Classification (IPC Global Partners, 2008)

Classification	Description
Generally Food Secure	More than 80% of households can meet basic food needs without atypical coping strategies
Borderline Food Insecure	For at least 20% of households, food consumption is reduced but minimally adequate without having to engage in irreversible coping strategies. These households cannot fully meet livelihoods protection needs.
Acute Food and Livelihood Crisis	At least 20% of households have significant food consumption gaps OR are marginally able to meet minimum food needs only with irreversible coping strategies such as liquidating livelihood assets. Levels of acute malnutrition are high and above normal.
Humanitarian Emergency	At least 20% of households face extreme food consumption gaps, resulting in very high levels of acute malnutrition and excess mortality; OR HH households face an extreme loss of livelihood assets that will likely lead to food consumption gaps.
Famine & Humanitarian Catastrophe	At least 20% of households face a complete lack of food and/or other basic needs and starvation, death, and destitution are evident; and acute malnutrition prevalence exceeds 30%; and mortality rates exceed 2/10000/day.

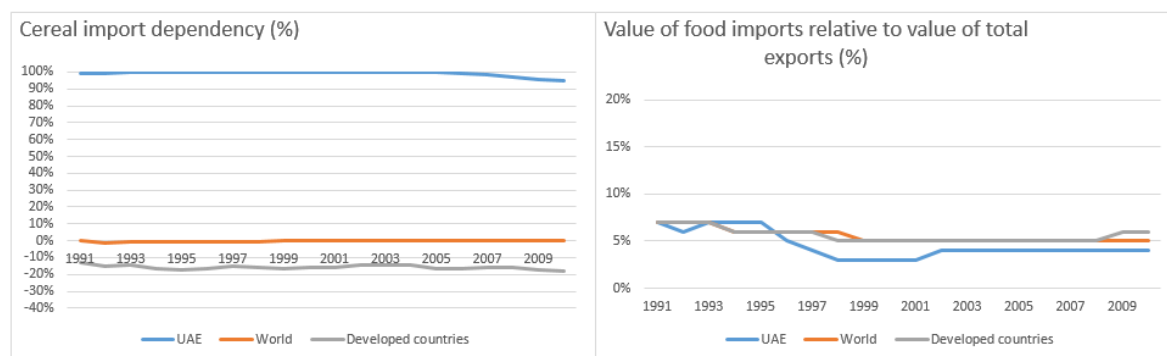
drivers of food security in 109 countries, including the UAE. It seeks to address the core issues of affordability, availability, and quality/safety through the evaluation and scoring of thirty-three (33) unique indicators, resulting in a range from 0 to 100, which enables inter-country comparisons possible (Table 2-2 provides a summary of the indicators). On the basis of country scores for each of these indicators, the GSFI divides countries identifies into four distinct quartiles to characterize their food security situation. These quartiles are: "Best Environment", "Good Environment", "Moderate Environment", and "Needs Improvement". Countries are defined as food secure if their resulting score in the highest quartile. In its latest overall rankings, the UAE received a score of 75.6 out of 89.0, indicating it is classified as having the "Best Environment" for food security (EIU, 2015).

The international Food Policy Research Institute (IFPRI) developed a food security index

Table 2-3: Stability indicators (source: FAO, 2015)

a) Cereal import dependency

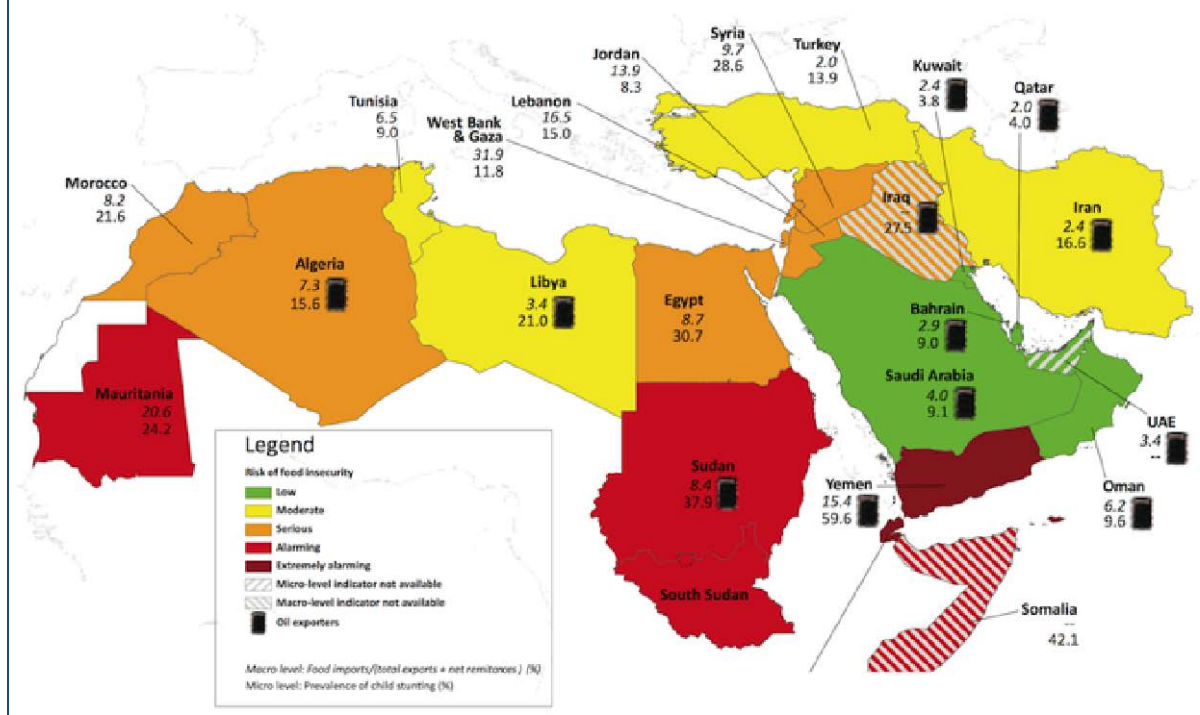
b) Import-export ratio



specifically for the MENA region (IFPRI, 2013). They extended the most common indicator for MENA countries, namely mineral resource wealth (mainly oil and gas), to also include food trade balance (ratio of total exports to food imports), agricultural potential (food production per capita), and the Global Hunger Index (GHI).³ This resulting composite index seeks to capture both the macroeconomic and household-level dimensions of food security. MENA countries are defined as having a "low risk of food insecurity" if all the values of the four chosen food security indicators are above the international average of this indicator and/or the countries are classified as high-income countries according to the World Bank's definition—a gross national income (GNI) of more than US\$11,906 per capita. Figure 2-4 illustrates the application of IFPRI's food security index to the MENA region. The UAE is classified as having a "Low Risk of Food Insecurity" within this classification system.

³ The GHI combines three equally weighted indicators: proportion of undernourished as a percentage of the population; prevalence of underweight in children younger than five (loss), and mortality rate of children younger than five (von Grebmer et al., 2009).

Figure 2-4: IFPRI's food security index as applied to the MENA region (Breisinger et al., 2012)



In summary, the key finding from a review of these food security classification systems is that the UAE is capable of ensuring access, affordability, and quality of its food supplies. While this finding would thus characterize the UAE as "food secure", at least in the macro sense, it is important to note that this is a relative standard resulting from comparisons with many countries whose food security situation may be dire. Moreover, while this finding may be true relative to some aggregate comparisons across countries, it tends to mask important information across segments of the population. This is because food insecurity is not experienced in a homogeneous way by the residents of a country. In the UAE, perceptions of food insecurity are driven by a number of socioeconomic characteristics such as income levels, non-discretionary spending patterns, and the relative prices of other commodities.

1.2. Food trade context

International food trade is a diverse and complex operation that can be a significant contributor to food security (Kenny, 1998; Hebebrand and Wedding, 2010; Chicago Trade Council on International Affairs, 2013). The expansion and diversification of the food trade can be attributed to many factors. First, the disciplines of food microbiology, food chemistry and food technology are continuously providing a broader range of foods by developing new and more sophisticated preservation, processing and packaging techniques which make foods safer, and less perishable and more attractive to the consumer. Second, rapid transport and improved handling methods have reduced the length of time and difficulties associated with moving food long distances, thus allowing traders access to new and far-away markets. Third,

consumers' tastes and food habits have become more varied as their incomes and purchasing power have risen, stimulating the demand for traditional and new foods from other regions.

International food trade plays a vital role in balancing the deficits of net food importers with the surpluses of net food exporters (Brooks, 2014). In the absence of trade, food prices would be higher in countries like the UAE which are net food importers. Such a situation is simply the result of markets seeking to bring national supply and demand into equilibrium. The absence of well-functioning international food trade market would certainly have an adverse impact on the food security status of households in the UAE. The situation is reversed for households in net exporting countries. In the absence of trade, food prices would be lower because of the inability to export surplus production (Brooks, 2014).

UAE food supply is highly dependent on international food trade flows. Of the three major sources of food supply: imports, local production, and food stocks, UAE food supply relies overwhelmingly on international food trade (FAO, 2014). This is due to the UAE's location in a hyper-arid environment where local agricultural production is limited. For the most recent year for which complete annual data is available from the FAO, about 87% of UAE food supply came from imports. This is highlighted in Table 2-5, where major food items are ranked in order of largest to smallest total domestic food supply item, where domestic food supply total is equal to UAE production plus net food imports from international food trade flows. There are several essential food categories for which imports account for upwards of 95% of domestic food supply (e.g., cereals, oil crops, sugar/sweeteners). Moreover, as the UAE is a major regional trade hub, significant food quantities are exported/re-exported, primarily to other GCC countries.

Table 2-4: Profile of UAE food supply (thousand metric tonnes), 2011 (FAO, 2014)

Rank	Food item	UAE Production	Net imports			Total domestic food supply	Net import share
			Current imports	Stock Variation	Exports & re-exports		
1	Cereals	133	2,981	-13	639	2,329	95%
2	Oil crops	0	1,077	2	22	1,057	100%
3	Sugar/Sweeteners	0	2,043	-435	600	1,008	100%
4	Milk	147	1,050	211	411	850	85%
5	Vegetables	176	893	0	146	747	92%
6	Fruits	262	1,008	89	363	734	96%
7	Miscellaneous	0	417	0	11	406	100%
8	Meat	131	418	1	31	388	75%
9	Vegetable Oils	342	834	-84	469	281	45%
10	Treenuts	1	276	0	9	267	100%
11	Pulses	0	352	-39	71	242	100%
12	Fish, Seafood	80	247	1	38	210	72%
13	Starchy Roots	10	183	0	10	173	95%
14	Spices	0	97	0	6	91	100%
15	Stimulants	0	107	8	49	66	100%
16	Eggs	29	31	0	3	28	49%
17	Animal fats	4	30	0	11	19	83%
18	Offals	15	4	0	0	4	21%
Total		1,330	12,048	-259	2,889	8,900	87%

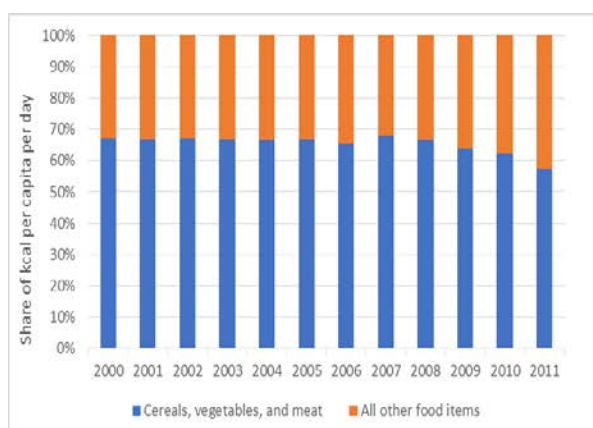
The lack of viable local production options implies that any disruption to international food markets is likely to be experienced more acutely in the UAE than in countries where local food production alternatives are available. This is particularly true for cereals, vegetables, and meat for which imports accounted for 95%, 81%, and 75%, respectively, of the supply of these food items in 2011 (see Table 2-4). Over the 2000-2011 period, the share of these food items have consistently averaged around 65% of the diet of residents in the UAE (see Figure 2-5a). Moreover, the UAE's combined resident and expatriate populations have been increasing rapidly, rising nearly three-fold over the period 2000-2011, or about 10.3% per year and qualifying the UAE as having one of the highest population growth rates in the world (UAE, 2010). Cereal import rates have increased an average of nearly 9.8% per year to keep pace (see Figure 2-5b).

Table 2-5: Global Food Security Index indicators (EIU, 2014)

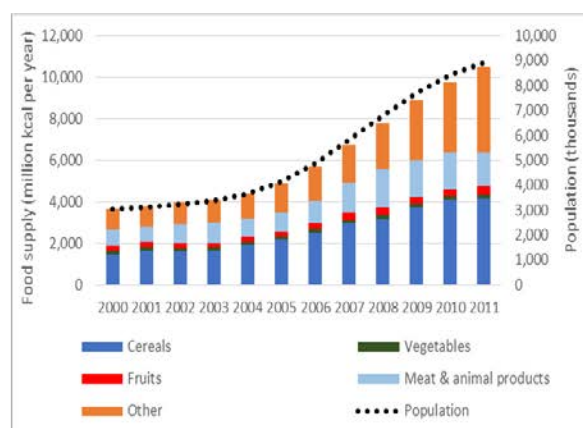
Affordability	Availability	Quality and safety
<ol style="list-style-type: none"> 1. Food consumption as a share of household expenditure 2. Proportion of population under global poverty line 3. Gross domestic product per capita (PPP) 4. Agricultural import tariffs 5. Presence of food safety net programmes 6. Access to financing for farmers 	<ol style="list-style-type: none"> 1. Sufficiency of supply 2. Average food supply 3. Dependency on chronic food aid 4. Public expenditure on agricultural research & development 5. Agricultural infrastructure 6. Existence of adequate crop storage facilities 7. Road infrastructure 8. Port infrastructure 9. Volatility of agricultural production 10. Political stability risk 11. Corruption 12. Urban absorption capacity 13. Food loss 	<ol style="list-style-type: none"> 1. Diet diversification 2. Nutritional standards 3. National dietary guidelines 4. National nutrition plan or strategy 5. Nutrition monitoring and surveillance 6. Micronutrient availability 7. Dietary availability of vitamin A 8. Dietary availability of animal iron 9. Dietary availability of vegetal iron 10. Protein quality 11. Food safety 12. Agency to ensure the safety and health of food 13. Percentage of population with access to potable water 14. Presence of formal grocery sector

Figure 2-5: Food supply trends in the UAE, 2000-2011 (FAO, 2015)

a) Per capita food supply

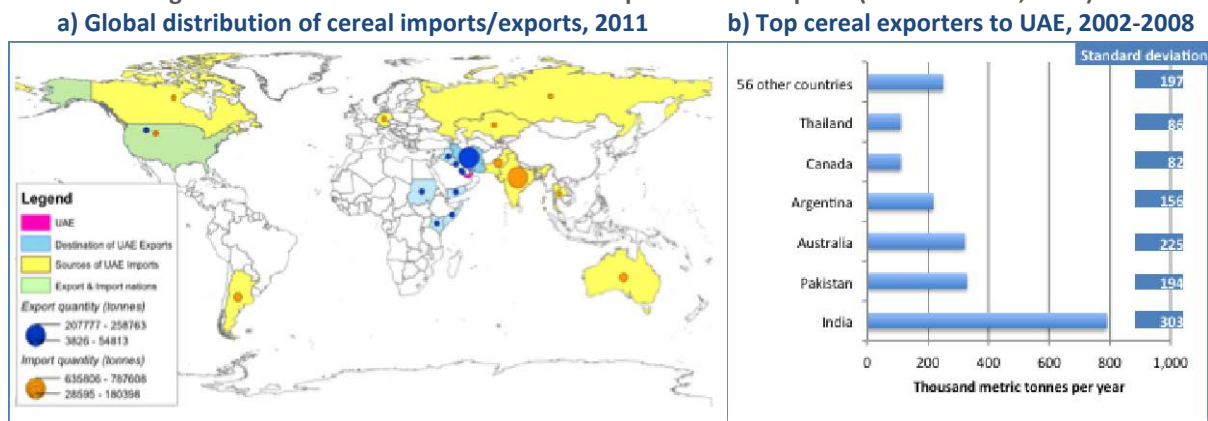


b) Food supply and population



Food trade flows for the UAE tend to be dominated by core groups of food exporting countries. The actual set of countries varies depending on the particular food item imported. For example, the majority of cereal imports such as wheat, rice, barley, maize, oats, millet, and sorghum are typically imported from a handful of countries, namely India, Pakistan, Australia, Argentina, Canada, and Thailand. Together, these countries accounted for an average of 88% of all cereal imports over the period 2002-2008 (FAO, 2014). From year to year, cereal imports from these countries can show large swings, as evidenced by high standard deviations when compared to average imported levels over the 2002-2008 period (see Figure 2-6b). Cereal re-exports from the UAE are also primarily focused on handful of countries, namely GCC and Eastern Africa countries (see Figure 2-6a). Hence, maintaining food security for the UAE depends, at least in part, on understanding the impact that climate change poses on the very countries upon which the UAE has historically come to rely for its food supply.

Figure 2-6: Characteristics of UAE cereal imports and re-exports (based on FAO, 2014)



1.3. Food price and climate change context

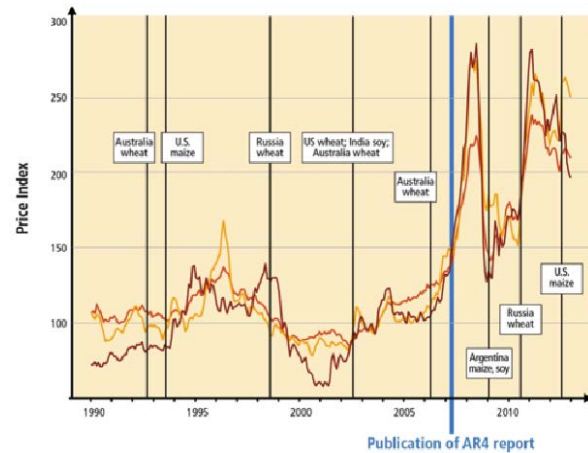
The food price crisis of 2008 focused world attention on the vulnerability of many countries to mostly non-climatic factors outside their control (Heady, et al., 2010). Whereas food prices had steadily dropped over the period 1920-2002 due to high US/OECD productivity levels and the “green revolution” in Asia, prices steadily increased since the early 2000s. Since then, food prices have increased dramatically on world markets, culminating in the price shocks of 2008. While the price of a tonne of wheat cost US\$106 in January 2000, it rose to US\$196 in January 2007, and reached US\$440 in March 2008 (Wiggins and Levy, 2008). These price escalation trends are consistent for other food items as evidenced by similar trajectories for the cereal and food price indices (see Figure 2-7).

The volatility of food prices can be explained by a combination of mostly non-climatic factors (Mittal, 2009; von Braun and Tadesse, 2012). These include rising supply costs (i.e., for nitrogen fertilizer, machinery operations, transport to world markets), country grain export bans, rising demand due to growing consumer incomes, investor speculation in commodity prices, as well as poor harvests in some exporting countries (Brown and Funk, 2008; Seo and Rodriguez, 2012). For example, the Russian wheat export ban in 2010 led to

large price increases in global markets (see Box 2-2). Together with other exporters, such actions have helped to create an environment where food price spikes associated with climatic factors are more likely in the future (Welton, 2011).

The escalation of food prices has resulted in demonstrations in several countries of North Africa and the Middle East (Kumetat, 2009; Lagi et al., 2011). Roughly 74 low-income and 71 middle-income countries were adversely affected by food price increases to the extent that violent street protests erupted in many nations, with Africa witnessing food riots in at least 14 countries across the continent (Berazneva and Lee, 2011). While such unrest did not occur in the UAE, the country is susceptible to global price fluctuations and price inflation, as are other GCC nations (Woertz et al., 2008).

Figure 2-7: Global price indices over time (IPCC, 2014)



Note: vertical lines indicate events when a top 5 producer of a crop had yields 25% below trend line (indicative of a seasonal climate extreme)

Box 2-1: The global impacts of Russia's 2010 grain export ban (Welton, 2011)

In the summer of 2010, Russia experienced a heat wave where temperatures exceed those recorded at any time within that past 130 years. As news of this disaster, and the resulting drop in Russia's grain crop became known, international grain prices increased dramatically. In an effort to protect local consumers and local meat producers, the Russian government instituted a grain export ban that pushed internationally traded grain prices higher. Notably, countries that had contracted to buy Russian wheat at low rates were required to pay the higher international rates, resulting in serious financial shocks to economies of food importing countries.

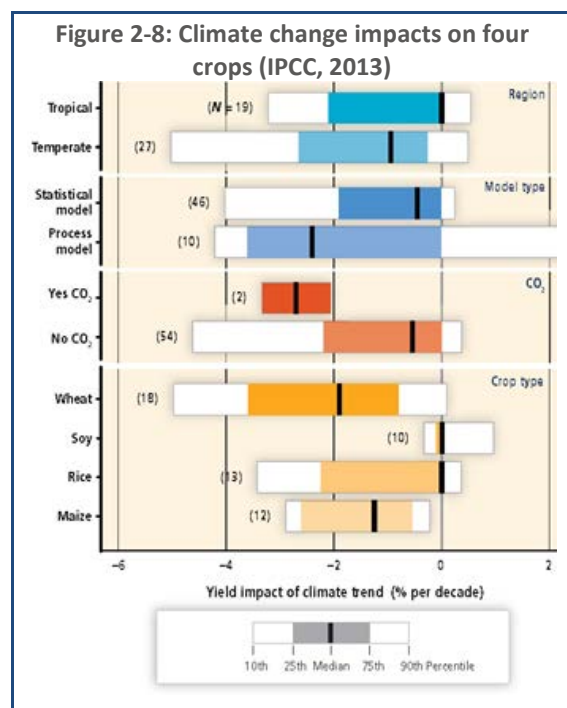
The food price crisis of 2008 also highlights the linkages between food supply and international financial markets (World Bank, 2012). In 2008, the financial crisis that began in the United States and Europe, led global markets to become much more volatile and caused commodity prices to rise significantly (IPCCa, 2014). This volatility in commodity prices was in large part due to a decreasing trend in food supplies available for purchase on the global market. This shrinking share of food on the global market is sometimes referred to as "market thinness" (FAO et al., 2011).⁴ The processes driving market thinness are expected to continue into the foreseeable future, thus recent high food prices may persist for some time (Fischer et al., 2002; World Bank, 2012). Moreover, since the dirham is pegged to the US dollar, the UAE was strongly affected by the simultaneous rise in food

prices on the world market and the weakness of the US currency (Kumetat, 2009).

⁴ Market thinness refers to a conditions in which only a small proportion of world food production enters international markets through trade (World Bank, 2009).

Climate change is expected to exacerbate the future volatility of food prices (Diffenbaugh, et al., 2011). Indeed, some of the most profound and direct impacts of climate change over the next few decades will be experienced by agricultural and food production systems (Brown and Funk, 2008). Increases in short-term weather hazards such as dry-spells and droughts will significantly impact the viability of existing cropping methods, adding to market uncertainty and commodity price volatility. Likewise, changes in storm frequency and severity could interrupt commodity supply chains and sea-based transportation routes around the world (UNCTAD, 2013). Early research shows that the future impact of climate change on crop yields have found a range of adverse impacts on agricultural yields in food-producing countries (Fischer et al., 2002; Parry et al., 2004; Breisinger et al., 2012).

Climate change is expected to increase the severity of a variety of weather-related hazards that will negatively impact agricultural production throughout the world (Brown and Funk, 2008; Nelson, et al., 2010). The Intergovernmental Panel on Climate Change (IPCC) has reviewed the range of peer reviewed literature and concluded with high confidence that the effects of climate change on crop and terrestrial food production are already evident in several regions of the world (IPCC, 2013).⁵ Notably, the IPCC has determined that adverse impacts of climate change on crop production is more prevalent than positive ones. This is illustrated in Figure 2-8 which summarizes the impact of recent climate trends on yields for four major crops. Boxplots indicate the median (vertical line), 25th to 75th percentiles (colored boxes), and 10th to 90th percentiles (white boxes) for estimated impacts in each category, and numbers in parentheses indicate the number of estimates. Each of the four crops has already experienced adverse impacts from climate change on production levels. Wheat shows the strongest negative trend with yields decreasing roughly between 1% and 3.5% per decade.



⁵ Based on results from the peer-reviewed literature using different methods (i.e., physiological process-based crop models or statistical models), spatial scales (stations, provinces, countries, or global), and time periods (median length of 29 years).

Numerous studies argue that climate change will contribute to increased food prices by 2050, with estimated increases ranging from 3 to 84% (Hertel et al., 2010; Calzadilla et al., 2013; Lobell et al., 2013). For example, Nelson et al (2010) estimated that the contribution

Table 2-6: World cereal price estimates due to climate change (Nelson, 2010)

Crop	Scenario	Average price increase in 2050 relative to 2010		
		All contributing components of price		Climate change component of price increase
		No mitigation of climate change impacts	Perfect mitigation of climate change impacts	
Wheat	Baseline	54.2%	23.1%	31.1%
	Optimistic	43.5%	23.4%	20.1%
	Pessimistic	58.8%	24.4%	34.4%
Rice	Baseline	54.8%	19.8%	35.0%
	Optimistic	31.2%	18.4%	12.8%
	Pessimistic	78.1%	19.5%	58.6%
Maize	Baseline	100.7%	32.2%	68.5%
	Optimistic	87.3%	33.1%	54.2%
	Pessimistic	106.3%	34.1%	72.2%

of climate change on the prices of wheat, rice, and corn would be considerable. Using a modeling framework that incorporated a partial equilibrium agricultural model, a hydrology model, and a crop model, the study estimated national crop productivity and corresponding world food prices under a range of climatic and other assumptions over the period 2010 through 2050. Depending on the level of economic and population growth, the

study predicted that wheat prices, adjusted for inflation, would rise by 20.1% to 34.4% by 2050 due to climate change alone. Similarly, rice yields are projected to diminish, leading to an increase in prices from 12.8% to 58.6%, while corn prices would rise from 54.2% to 72.2% (see Table 2-6). In other words, an already volatile global food price situation is expected to worsen with climate change. The increased instability of agricultural yields of cereals and other crops under climate change will have the effect of aggravating market thinness, which in turn is expected to lead to even greater food price volatility.

1.4. UAE food security policy context

Within the UAE, there is a sophisticated institutional and regulatory system to ensure the quality, safety, and cost-effectiveness of its food imports (Taha, 2013).

As a member of the GCC, the UAE collaborates with the other member states to unify the rules and regulations governing national food imports. The reference point for this collaboration is the Codex Alimentarius, a collection of internationally adopted food standards which aims to protect the health of consumers, ensure fair practices in the food trade and promote the coordination of all food standards work. The Gulf Standards Organization (GSO), chaired by Qatar, is responsible for developing food standards in the GCC/Yemen and has been working to harmonize existing GCC standards within the guidelines of the

Box 2-2: Institutional framework overseeing food imports in the UAE (Taha, 2013)

The Emirates Authority for Standardization and Metrology (ESMA) is responsible, in cooperation with other members of the GSO, for either developing or adopting all food import standards. Senior officials from ESMA represent the UAE at GSO meetings.

The Ministry of Environment and Water (MOEW) is the national coordinating body responsible for establishing and enforcing food safety regulations and laws based on recommendations made by the GSO as well as its National Food Safety Committee (foodstuffs) and Veterinary Committee (meat & poultry).

Local Health agencies in each UAE municipality are responsible for enforcing federal food safety standards on imported foods through its respective food control authority.

Codex Alimentarius, ISO and other international organizations. Nearly 1,000 food and food-related technical regulations and standards have been developed or updated by the GSO (Taha, 2013). Within the UAE, the role of the key regulatory agencies that oversee food imports are briefly described summarized in Box 2-2.

Favorable terms of trade and a well-developed logistics network have positioned the UAE as a key hub to facilitate international food trade (Canadian Trade Commissioner Service, 2012). The UAE market is classified as Customs Zones or Free Trade Zones with food imports arriving at any of the UAE's Customs Zones subject to duty under the GCC's Common Customs Law. Food destined for any of the 36 Free Trade Zones are exempt from duty, as are re-exports from UAE Free Trade Zones bound for third market destinations beyond the GCC Customs Zones. In general, an external tariff of 5%, the GCC's Common External Tariff (CET), is levied on all food imports to the GCC market, based on the GCC Unified Customs Law and Single Customs Tariff, enacted in 2003. No tariff quotas, nuisance rates or additional duties and taxes on imports are applied. The CET of 5% is also the most-favored-nation rate (MFN rate) and the UAE typically grants MFN treatment to its food trading partners.

As a predominantly food-importing country, the UAE's food security has received priority attention on the policymaking agenda. Before and since the food price crisis of 2008, food security policies focused on ensuring that the impacts of food price spikes were suitably mitigated. Such policies included food subsidies, price controls, wage bonuses, and others

(see Table 2-7). The basis for these policies is Article No (4) of Federal Law No. (24), passed in 2006, which provided authority for the Consumer Protection Department to, among other functions, monitor, control and curb food price hikes. To a large extent, consumer protections have been exercised by exempting most food imports from customs duties.⁶

Table 2-7: UAE policies to mitigate food price volatility (DoED, 2011)

- Reduction of customs duties on imports
- Reduction or banning of exports.
- Releasing quantities of commodity stocks to stabilize prices
- Raising the prices crops bought from farmers to encourage
- Adoption of policies to encourage agricultural investment locally and abroad.
- Using and encouraging modern technologies to increase productivity (increasing quantity – reducing cost or both)
- Subsidizing primary commodity in cash or in kind.
- Stabilization of commodity prices (forced pricing)
- Determine profit margins as a percentage of the cost of the
- Activating the role of cooperative societies and agricultural marketing centers to sell at low profit margins.
- Reducing goods circulation chain to allow selling products from producer to consumer directly.
- Encouraging agricultural manufacturing, to reduce waste ensure availability of goods throughout the year.
- Raising awareness of consumers to rationalize consumption

Food security policies have also been focused on a number of complementary areas to ensure adequate and affordable supplies of key food staples to cope with growing demand for food (DoED, 2011). First, physical stockpiling has been proposed to build up strategic in-country reserves of food (DMCC, 2012). This strategy involves effective management as well as an extensive storage facility infrastructure. Second,

for UAE citizens, the stability of food prices extends, if necessary, to the distribution of food commodities such as rice, flour, water at subsidized prices, with quotas established according

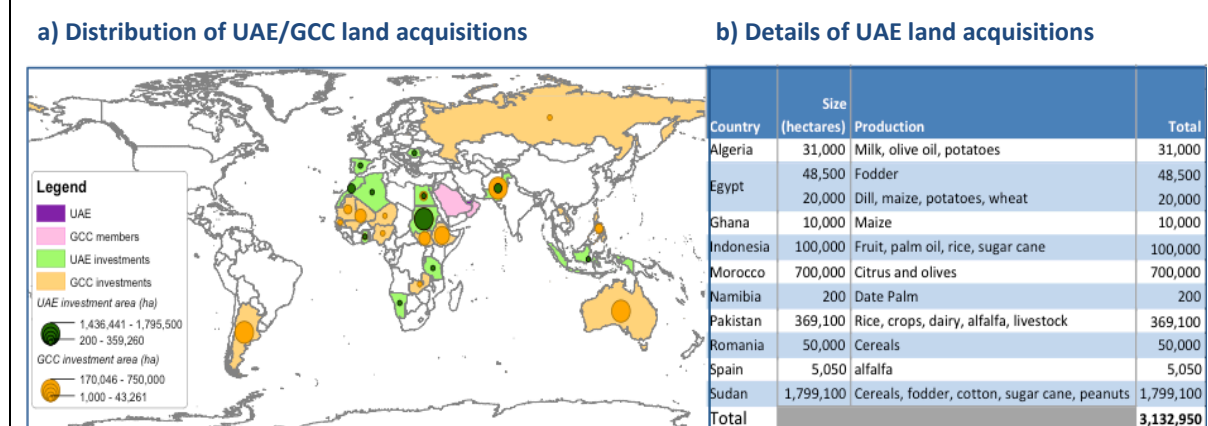
⁶ Some food imports are still subject to customs duties, among them frozen chopped beef, meat of sheep and goats, some types of fish, natural honey, temporarily stored and uncooked frozen vegetables, some grease and fats and oils, lentils, beans, spices and tomato sauce.

to family size. For example, the per capita share of rice is 6.5 kg per month for a family of 6 persons (DoED, 2011). Third, increasing the share of local agricultural production as a share of GDP is being urged, particularly in the Abu Dhabi Emirate where the EAD's Comprehensive Soil Survey concluded that there are approximately 400,000 hectares suitable for agricultural expansion. Supporting farmers through providing services, increasing their income, and facilitating foreign investments is also part of this policy framework. Finally, demand-side policies that focus on the need to reduce the level of food wastes and other inefficiencies in the food supply chain are under consideration.

Despite such food security policies, a recent socioeconomic survey found that there is a strong perception among all segments of the UAE population that they do not have enough income to meet the challenges of rising prices for food and other items (Muhamad et al., 2010). In a survey conducted in 2008, 300 randomly selected respondents from different ethnic groups across the seven emirates were questioned regarding their perceptions of price increases. The survey was designed to analyze the impact of food price increases on the households in UAE. It was motivated by price trends that showed significant increases in recent years affecting the UAE diverse population in very different ways. A total of 196 out of 300 respondents completed the survey (65%), offering a basis by which to assess local perceptions of the economic and social impacts of increases in prices. The results showed that the majority of the respondents were adversely affected by the recent increase in prices, with about 62% of non-national respondents reporting that they do not have enough income to meet their daily needs, compared to about 10% for national respondents. The price increases were highest for food, rent, education, and healthcare. Their analysis showed that the effect of high prices varied among groups based on their age, ethnicity, gender, educational level and income. The overall conclusion of the study suggests that the increase in household incomes are lagging significantly behind the increases in food and other items, placing mounting stress on households' ability to cope.

In recent years, the UAE has embarked on a coordinated regional policy to buy or lease agricultural land abroad as way to pursue long-term food security (QFCA, 2010). The objective is to secure deals, particularly in other Islamic countries, by which capital and oil contracts are exchanged for guarantees that private corporations from the Gulf will have access to farmland and be able to export the produce back to the region (GRAIN, 2008). This policy appears to be well underway in the UAE with a total of 2.9 million hectares already under agreement, and another 0.3 million hectares in process. These outsourced lands are distributed across 11 countries (see Figure 2-9), with North Africa and Asia accounting for 97% of the total land area between them (82% and 15%, respectively). It is important to note that this type of information has been difficult to obtain given the proprietary nature of the agreements. The GRAIN article itself has been criticized as not being rooted in validated data. It is offered here as representative of an overall trend in the GCC countries, as opposed to "ground-truthed" quantitative data.

Figure 2-9: UAE/GCC land acquisitions in other countries to promote food security (GRAIN, 2012)



To date, most if not all of the UAE land acquisitions abroad appear to not yet in full-scale production. This may be due to the fact that such acquisitions are complicated by logistical, jurisdictional, and local socioeconomic concerns. Physical land investments imply a reliance on a set of location-specific factors including adequate biophysical conditions, stable supply chain infrastructure, trustworthy governance, and rule of law (Zetland and Möller-Gulland, 2013). While there are substantial benefits for countries that sell/lease their land to the UAE, land tenure is an important consideration, since many purchased (or leased) regions are currently occupied by communities (Zhao and Xu, 2013). Addressing the distribution of monetary benefits and land tenure concerns is an important challenge to consider as long-term viability will likely depend on the cooperation of communities living on or adjacent to the land acquisitions (Zurayk et al., 2011).

Additional policies may need to be considered in order to ensure the long-term food security of the UAE. In the face of global market volatility, there are as yet untried financial instruments exist that could help manage exposure to market risk and volatility (World Bank, 2012). Virtual (as opposed to physical) food stockpiles represent one example. These are pre-paid guarantees that grain will be available for purchase at a fixed price, for a fixed period of time. *Futures* contracts are a form of virtual stockpiles, where a purchaser promises to buy a fixed quantity of a commodity at a fixed price for a fixed time period. *Options* contracts, the other main type of virtual stockpile, give the purchaser the right, but not an obligation, to purchase a commodity at a fixed price for a fixed amount of time (World Bank, 2009). Because of the UAE's access to financial resources, futures contracts may be a particularly desirable strategy for to hedge against market volatility, with built-in flexibility. Options contracts, on the other hand, may be better suited to nations that have more domestic production than the UAE, so they can hedge against forecasts of bad domestic grain forecasts in advance.

In summary, the UAE has been active in crafting a range of policy mechanisms intended to promote food security. Preliminary findings show that much of the policy focus has been around the establishment of physical food storage infrastructure and agricultural land acquisitions abroad. For the purposes of this sub-project, analysis is underway to shed light on the economic impact of land investments (i.e., the land acquisition strategy) when

compared to virtual investments (i.e., futures contracts), when accounting for climate change. The land acquisition component of the analysis focuses on the very countries in which the UAE has so far invested to ensure its food supply. The virtual investment component of the analysis explores the impact of climate change using a parameterized simulation using Chicago Board of Trade (CBOT) market prices as a benchmark for market trends as compared to market prices that account for climate change.

1.5. Framework for food security indicators for the UAE

The discussion in the previous sections suggests several reasons why a two-tiered approach is needed for evaluating food security under climate change. First, the nature of food security indicators proposed in the literature infers that some indicators are appropriate at a national scale (e.g., food availability, food access) while others that are more appropriate to consider at a household scale (e.g., food affordability, food utilization). Second, the nature of food supply in the UAE (i.e., overwhelmingly from imports) is such that the agricultural productivity under climate change in other countries is more integral to the UAE's food security than local agricultural productivity under climate change. Third, most of the national policies that are currently in place to address food security in the UAE are aimed both at the role of government (e.g., food commodity tariff levels, attracting foreign investment, maintaining strategic food reserves) as well as the role of consumers (e.g., subsidies to reduce impacts of price increases, reducing wastes).

Hence, a framework for the assessment of food security under climate change in the UAE should address both the macro and micro scales. At the macro scale, a key indicator to explore is the degree to which food exporting countries on which the UAE has historically relied upon are projected to experience constraints in agricultural productivity due to climate change. Such constraints could lead to a decrease in the availability of and access to imported food items by the UAE, or at least adverse perturbations in availability and access. At the micro scale, a key indicator is the degree to which food at retail outlets throughout the UAE remains affordable under climate change. Affordability, a relative term, needs to be considered within the overall context of household expenditures and how household incomes are projected to change over time.

2. Methodology

This section provides an overview of the methodological approach for quantifying food security risks under climate change for the UAE. The section begins with a brief overview of the core research question underlying the study. This is followed by a summary of the study's goals/objectives, conceptual approach, key analytical steps, and modeling framework. The section concludes with a discussion of the approach adopted for making accessible an ability by interested stakeholders to visualize the results of the analysis and to conduct food security risk analysis.

2.1 Core research question

How could the impacts of climate change on food exporting countries impact the long-term food security of the UAE at both the national and household levels? This is the core research question underlying the methodological approach. Addressing this question requires attention to a number of interlinked issues such as UAE food supply patterns, global climate change projected impacts on agriculture, performance of international trade and financial markets, UAE household income/expenditure characteristics, food security policy initiatives underway, among others. As discussed in the sub-sections that follow, addressing this question has requires extensive data acquisition and numerical modeling in order to offer a quantitative basis by which to understand the economic impacts of climate at both the national and household level, quantify the costs and benefits associated with alternative food security strategies, and identify ways to mitigate future risks to food supply.

2.2 Goals and objectives

The overall goal of the Food Security and Climate Change sub-project is to better understand the policy implications for the UAE associated with climate change impacts and food security at both the macro (i.e. national) and micro (i.e., household) levels. This involves a quantification of the UAE's vulnerability to climate change regarding food supply and demand. It also involves an assessment of adaptation responses that can best mitigate long-term food security risks. There are five major objectives, as outlined in the following bullets.

- *Characterize current and future food supply.* Establish baseline and projected food supply and demand patterns in the UAE. For baseline food supply, this involved the development of a database that incorporated historical information on local agricultural production, international food trade flows to/from the UAE, national food balances for crops and livestock, and producer food prices. For future food supply, this involved quantifying future climate change impacts on the agricultural productivity and food export prices for two sets of countries, namely major food exporters to the UAE based on historical food trade trends and specific countries for which the UAE has entered into agricultural land purchase/lease arrangements.

- *Characterize current and future vulnerable groups in the UAE.* Establish baseline and projected household budget expenditures. This involved the development of a database regarding the share of food in household budgets relative to income strata. This was the metric used to assess the vulnerability of social groups in the UAE that may be particularly vulnerable to future food price shocks associated with climate change. The types of groups that were considered in the analysis consisted of both Emirati and expatriate households.
- *Develop food security vulnerability indices at the macro and micro levels for the UAE.* This involved the analysis of the food supply and household expenditure databases to develop a UAE-specific vulnerability indices. The aim of these indices is to offer insight on the risks associated with continued reliance on historical food trade patterns (i.e., food imports) and the vulnerability of households to future food price increases (i.e., local food prices increases).
- *Assess adaptation options.* Identify and discuss a set of potential adaptation options for enhancing UAE food security under climate change. On the macro side (i.e., international food trade flows), three options were considered, namely continued foreign agricultural land acquisitions, virtual food stockpiling, and increased local agricultural production. On the micro side (i.e., local food prices), the advantages and disadvantages of current food security policy options were reviewed.
- *Develop a food security risk software program.* Synthesize all inputs and outputs into a user-friendly tool. Such a tool is intended to enhance transparency of the analysis and provide ready access for stakeholders and partners to explore additional details of UAE food supply and demand, with and without climate change.

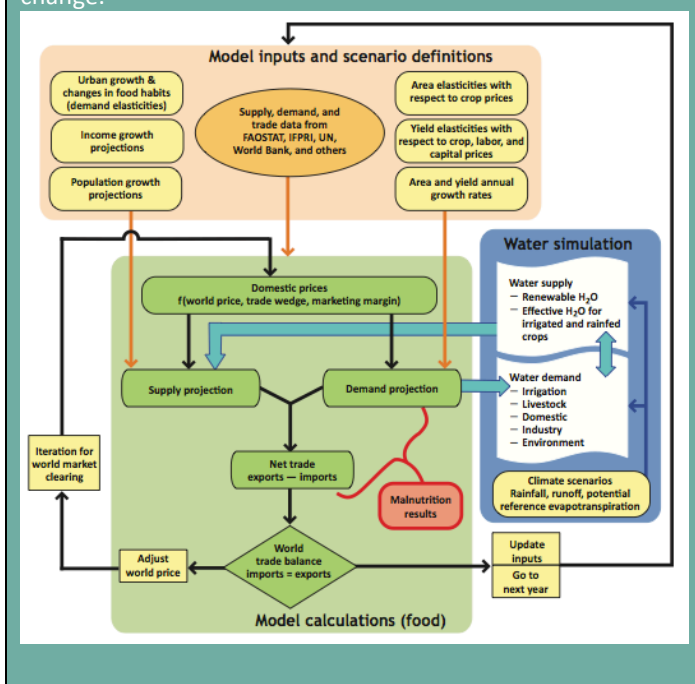
2.3 Foundational aspects

There were three main aspects that were foundational to the methodology applied in the study. First, to assess macro-level (i.e., national level in the UAE) food security issues, an econometric modeling approach was used to estimate food supply and trade risks under climate change. Such a modeling approach is able to integrate a wide range of pertinent country-level and global information into a single analytical platform to support food security risk assessments. At the country level, information is required on national crop production and soil characteristics, crop irrigation infrastructure, historical and projected climatic patterns, and other factors. At the global level, key modeling outputs include global projections of food demand, food trade flows, world prices with and without climate change, and other parameters. Such capabilities are incorporated in the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) which consists of a network of linked economic, water, and crop models, and was selected as the basis for estimating the impacts of climate change on the food security of the UAE (see Box 3-1).

Embedded in IMPACT is a methodology and system of equations that characterize agricultural productions and food prices under climate change. A total of 115 geopolitical regions, 126 hydrological basins, and 281 Food Producing Units (FPU) are represented within

Box 3-1: IMPACT modeling framework (Nelson, *et al.*, 2010)

The IMPACT model is a computable global equilibrium model developed by the International Food Policy Research Institute (IFPRI) to examine alternative futures for global food supply, demand, trade, prices, and food security. It is capable of providing global projections of agricultural commodity supply, demand, trade, and food prices within the context of climate change.



the model. Within each region, supply, demand, and prices for agricultural commodities are determined on an annual basis. All regions are linked through international food trade. Supply and demand functions incorporate elasticities that approximate the underlying production and demand characteristics. World agricultural commodity prices are determined annually at levels that clear international markets.⁷

Second, to assess micro-level (i.e., household level in the UAE) food security issues, a spreadsheet modeling framework was used to estimate the share of household expenditures on food, with and without climate change. This involved the development of an analytical system capable of estimating of the share of current

and future household income that is spent on food items while integrating a number of key assumptions regarding disaggregated consumer price indices, household income growth rates, and climate change impacts on local food prices. For the purpose of the analysis, vulnerable groups within the UAE were defined as any household located within any emirate whose share of food expenditures in monthly household budgets exceeds a certain level.

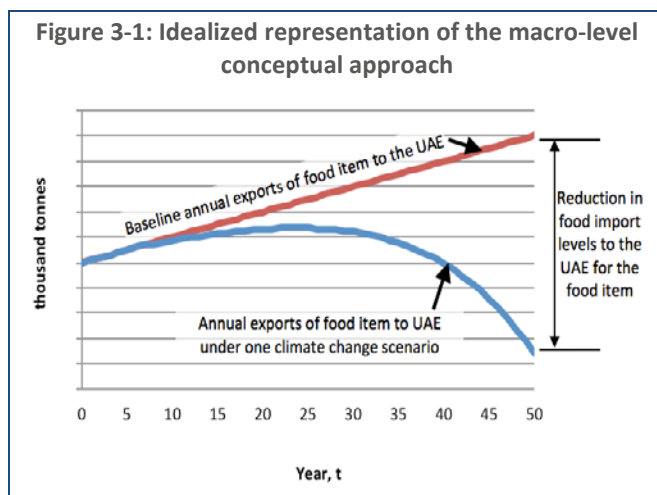
Third, a scenario approach was applied to address issues of uncertainty. A scenario is simply a representation of a plausible future under certain conditions. It is not a prediction of the future, but rather a narrative concerning a potential future given certain assumptions. Several scenarios were considered; a “Baseline Scenario” (or Business-as-Usual scenario), corresponding to a future where the climate of food exporting remains consistent with historical trends and a number of “Climate Impact Scenarios” corresponding to a future climate in food exporting countries consistent with the emissions scenarios proposed by the IPCC. Each scenario considered a planning horizon with a 2010 Base Year and a 2050 End Year.

⁷ There is a large literature devoted to the development and applications of IMPACT (see, for example, Nelson, *et al.*, 2010; Rosegrant, *et al.*, 2014; Waithaka, *et al.*, 2013; and Wheeler and von Braun, 2013). The reader is kindly referred to this literature for a comprehensive overview of the details of the model.

2.4 Conceptual approach

The implementation of the foundational described in the previous section implied the need to quantify food security vulnerability under climate change at two different scales. At the macro level, or UAE national scale, understanding food insecurity risks required the use of IMPACT's agricultural-econometric modeling framework to assess the level of vulnerability associated with continued reliance on the UAE's historical food import patterns. At the micro level, or UAE household scale, understanding food insecurity risks required the use of the spreadsheet analysis framework to assess the level of vulnerability associated with future household food expenditure patterns relative to overall household spending.

For the macro-level assessment, an idealized representation of the approach is provided in Figure 3-1. As an analytical construct, food insecurity risks at the national level were equated to the potential decline in food imports from countries on which the UAE has historically

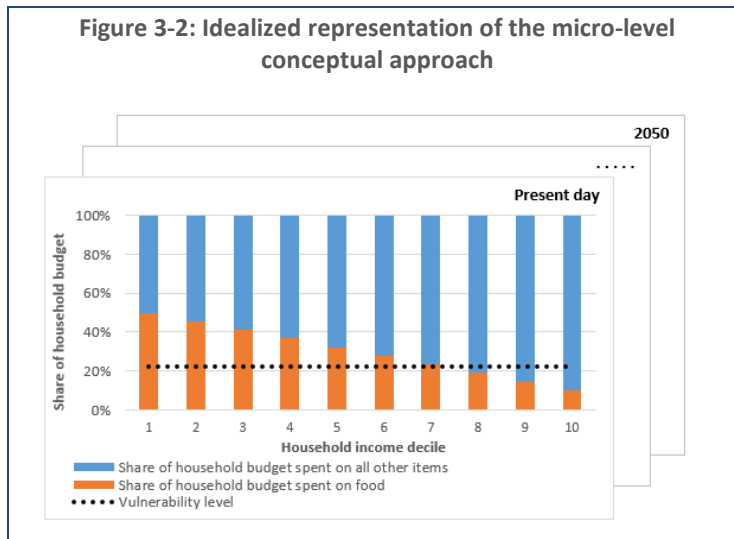


relied. Under a Baseline scenario, annual exports of food to the UAE for all major food-country combinations was projected on the basis of future demand and production characteristics (i.e., red line in Figure 3-1). Under the Climate Impact scenarios, available food exports to the UAE for the same food-country combinations were assumed to decrease proportional to the decline of agricultural productivity under climate change (i.e., blue line in Figure 3-1).

Annual and cumulative food export reductions were then estimated for each country-food combination for each Climate Impact scenario. Upon estimating the import gaps for all country-food combinations, the results were standardized into a scale from 1 to 10, with 1 indicating the lowest risks to future imports under climate change and 10 indicating the highest risks to future imports under climate change. This approach enabled direct comparisons regarding the future vulnerability of imports to the UAE for a comprehensive set of country-food combinations. In other words, each of the countries upon which the UAE has historically relied for the import of food items (i.e., cereals, vegetables, sugar, meat, etc) was assessed under conditions of climate change.

For the micro-level assessment, an idealized representation of the approach is provided in Figure 3-2. As an analytical construct, food insecurity risks at the household level were equated to the share in household budgets taken up by food purchases. UAE households were disaggregated according to income deciles. In the present day, household vulnerability was characterized relative to the share of food purchases above a UAE-specific standard for UAE households (i.e., percentage points in the brown bars above the dashed black line in Figure 3-2 for the Present day). Under the Climate Impact scenarios, household vulnerability

was characterized through relative to the change in household food expenditure shares, based on consumer food prices derived from the IMPACT model results and subject to assumptions regarding the consumer price index and household income growth levels. (i.e., percentage points in the brown bars above the dashed black line in Figure 3-2 for the years after the Present day through 2050).



Annual and cumulative deviations from the household food expenditure standard were then estimated for each income decile for each Climate Impact scenario through 2050. Upon estimating the real (i.e., discounted) deviations, the results were standardized into a scale from 1 to 10, with 1 indicating the lowest household vulnerability to future food price increases

under climate change and 10 indicating the highest household vulnerability to future food price increases under climate change. This approach enabled direct comparisons across UAE households regarding their future vulnerability to food price volatility. In other words, each of the household deciles were characterized relative to their vulnerability under conditions of climate change, subject to certain governing economy-wide assumptions (e.g., overall inflation) and decile-specific assumptions (e.g., income growth).

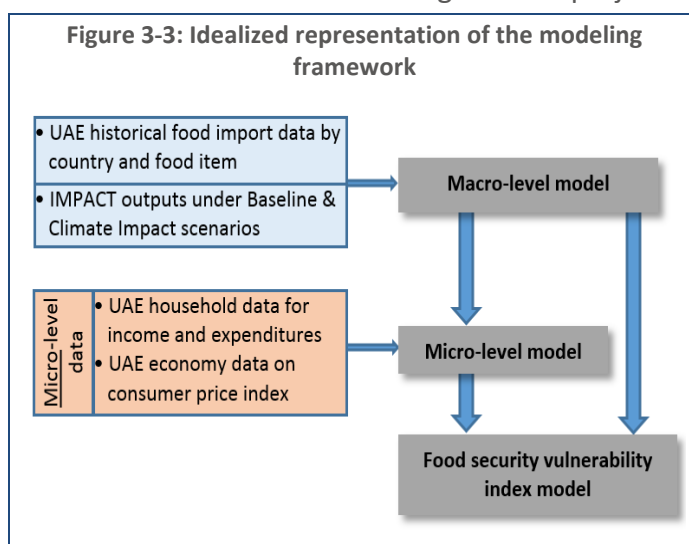
2.5 Key analytical steps

The analysis relied heavily on data and numerical modeling techniques. Data acquisition was focused on characterizing historical food supply/demand as well as household food expenditure patterns in the UAE. Macro-level analysis was focused on modeling the linkages between the production of key food commodities at the global level and food demand and security at the UAE national level, all within the context of scenarios of future climate change. Micro-level analysis was focused on modeling the linkages between the inflation, consumer food prices, and household expenditures within the context of scenarios of future climate change. Implementing the methodological approach involves a number of analytical steps, each of which is summarized in the bullets below.

- *Step 1: Establish historical and future UAE food demand.* An essential starting point was to establish baseline food demand patterns in the UAE. This consisted of a characterization of the nutritional content of typical UAE diets as well as per capita consumption over the recent past. This information was integrated into a plausible

projection of future food demand in the UAE over the period 2010 to 2050, after accounting for national population growth.

- *Step 2: Establish historical and future patterns of food imports.* This involved three key steps. First, a comprehensive and highly disaggregated database on food imports was assembled for the recent past to identify key trends, food suppliers, and issues of prominence. Second, this database was analyzed to produce core conclusions about where the UAE obtains its food, the volatility of annual food import costs, and other food supply indicators for the historical period. Third, this information was integrated into a plausible projection of future food demand and supply patterns in the UAE over the period 2010 to 2050, after accounting for national socioeconomic growth and global food price forecasts.
- *Step 3: Project food import gaps and prices with and without climate change.* This step focused on quantifying future climate change impacts on agricultural productivity and food export prices, and involved two key steps. First, each of the country-food import combinations were analyzed under a set of Climate Impact scenarios to compare future agricultural productivity of food exporting countries to projected food imports by the UAE. Second, any resulting gap in food import levels to the UAE relative to baseline trends was quantified on an annual and cumulative basis.
- *Step 4: Characterize household food expenditures with and without climate change.* This step focused on quantifying the nature of household income and expenditures, and involved three key steps. First, trends in the UAE consumer price index were evaluated for the recent past and projected into the future. Second, historical household expenditures on food and other items were evaluated relative to income deciles. Third, future shares of food expenditures relative to total household budgets were projected on the basis of a set of assumption regarding income growth, inflation, and food prices.
- *Step 5: Calculate macro-level and micro-level indices of food insecurity.* The final step in the analytical sequence was to integrate the outputs produced in the previous steps into a series of calculations to provide an estimate of the vulnerability of food-country combinations at the macro-level and household types at the micro level.



2.6 Modeling framework

The calculations of vulnerability indices required the development of two linked modeling frameworks. An idealized representation of the components and analytical flow sequence appears in Figure 3-3. As can be seen in the Figure, there are six (6) distinct components to the modeling framework. The two boxes at top left correspond to a set of databases that were developed to serve as input to the macro-level analysis; the box at the lower left corresponds to databases developed to serve as input to the micro-level analysis. On the right side of the flow chart, the top two boxes correspond to the two modeling levels – macro and micro; the box at the bottom right corresponds to the model developed calculate the vulnerability indices. The paragraphs that follow provide an overview of each element of the modeling framework.

- *Food import data.* The UAE's historical food import trends represented the point of departure for assessing macro-level food security under climate change. Historical food import levels were obtained from FAO trade matrices and cross-checked against available foreign trade statistics from the NSB where possible.
- *IMPACT outputs.* The results of IMPACT model runs were used as the basis to estimate the impacts of climate change on the agricultural productivity of the UAE's major trading partners, as developed by IFPRI.
- *Micro-level data.* The characterization of the profile of UAE households was based on data obtained from the NSB and a number of other sources. From these resources, a detailed database on household income and expenditure characteristics was constructed.
- *Macro-level model.* The macro-level model integrates all of the data from the FAO's trade matrices and IMPACT outputs to compare past food exports to the UAE of major food exporting countries with future food exports to the UAE of the same major food exporting countries under climate change.
- *Micro-level model.* The micro-level model integrates household level data and climate change impacts on future food prices to develop estimates of the magnitude of climate change-driven food price impacts on UAE households.
- *Food security vulnerability index model.* This model calculates the macro-level and micro-level indices of food security under climate change. It uses the outputs of the other two models in these calculations. For each level, the indices themselves are computed on a relative scale.

2.7 Food security analysis accessibility

Achieving the last objective of the study (i.e., *Develop a food security risk software program*) involved the development of a risk assessment software program. This was carried out in order to make accessible both the actual results of food security analysis, as well as offer the capability to interested stakeholders to conduct subsequent analyses. To this end, a model was developed – the Emirates Food Security under Climate Change model (EFSeCC) –

codifying all the data assumptions, modeling techniques, and vulnerability index calculations. The tool is essentially a macro-driven Graphical User Interface (GUI) built in Excel software that implement the sequence of analytical steps in the modeling framework described earlier. These steps evaluate macro- and micro-level food security risks for the UAE under a range of climate change scenarios. Using the outputs of IMPACT that estimates impacts on agricultural productivity and its resulting effect on world food prices, EFSeCC provides a flexibility for exploring alternative food import assumptions, consumer food prices, income growth trends, food consumption characteristics, and many other factors and assumptions.

There were five (5) specific aims associated with the substantive and visual design of EFSeCC. These aims have been established in response to feedback received from AGEDI stakeholders and partners. They were reflected during the model design process in order to ensure, as much as possible, that the model's visual and substantive designs are closely aligned with priority concerns of policymakers and decision makers. A description of each aim is provided in the bullets below.

- *Consistency:* This aim seeks to ensure that the model is designed to be consistent with the methodological approach, assumptions, and analytical steps documented in this Technical Report.
- *User-friendliness:* This aim seeks to ensure that the model is intuitive, easy to navigate, and useful to experts for use in research as well as to policymakers for exploring implications of specific food security policy options.
- *Transparency:* This aim seeks to ensure that the internal databases of the model are readily accessible for review and/or updating by the user. This offers the opportunity for a user to adjust the range of assumptions to reflect updates to food production and consumption patterns.
- *Flexibility:* This aim seeks to ensure that the model offers the capability to explore food import characteristics by exporting country and food type, as well as incremental costs of food imports under climate change by either exporting country or food type.
- *Focused:* This aim seeks to ensure that model design also incorporates a focus on a) certain countries in which the UAE has made agricultural land acquisitions in an effort to enhance food security and b) the vulnerability of specific communities with the UAE who may be vulnerable to future food price spikes.

Eventually, EFSeCC will be incorporated into the web-based LNRCCP portal that will contain all visualization tools developed for the 12 studies in the programme. The initial screen seen by the user upon accessing the LNRCCP portal website is shown in Figure 3-4a. Clicking on the food security sub-project icon under the “Systems” strategic theme (lower right icon encircled in red) opens the page in Figure 3-4b, which offers options to either review background documents (top icon), run EFSeCC (middle icon), review useful links (bottom icon), or return to the LNRCCP opening page (white hyperlink). Clicking on the EFSeCC middle icon opens the page shown in Figure 3-4c. The plan is for users to be able to run EFSeCC directly from the web or alternatively, download the model to a PC and conduct runs locally.

EFSeCC's main menu consists of three options. These are indicated in Figure 3-4c by the three icons in the left frame. Clicking on the top icon (Assumptions) provides entry to a series of pages where users can review default assumptions or replace those assumptions with those that are more appropriate or up-to-date. Clicking on the middle icon (Analysis) provides entry to a series of pages where users can explore the public health co-benefit impact of changing targets (i.e., the ambitiousness of policy implementation) within the framework of Abu

Figure 3-4: Components of the LNRCCP portal for the food security study



Dhabi's Climate Change Strategy. Clicking on the bottom icon (Reports) provides access to a series of reports that document the assumptions underlying a particular EFSeCC run. The tool has been designed to be highly intuitive for navigation. An overview of the model structure and functionality is provided in the Draft Visualizations Report (CCRGb, 2015).

3. UAE historical food imports

This section provides an overview of the approach used to establish trends in food imports to the UAE. The section begins with a brief overview of the overall approach. This is followed by a discussion of the mapping protocol used to harmonize the various databases used. The last subsection provide a synthesis of major results regarding food imports to the UAE. All the subsections below are offered as a high level summary of food import trends. The reader is kindly referred to the annexes of CCRG (2015c) for additional details of the mapping protocols and food import trends.

3.1 Introductory remarks

The UAE's historical food import trends represented the point of departure for assessing macro-level food security under climate change. This is due to the high reliance on food imports for ensuring food security. The UAE's historical food import levels were obtained from the FAO trade matrices. Detailed trade matrices covers the period 2002-2008 while aggregated trade matrices cover the period 2009-2011.⁸ With this information, a detailed database on historical imports was constructed that quantified quantities (in tonnes) of a total of 29 food items imported and the specific countries from which those imports were obtained. These statistics were cross-checked against available foreign trade statistics from the NSB. However, available national statistics were focused on high-level summaries of food import quantities and values for a subset of 13 food items. Also, the NSB data did not include information on the corresponding countries from which the imports were obtained. For these reasons, the UAE's historical and future food import levels were developed based on FAO data. The FAO data was then incorporated into the EFFSeCC model databases.

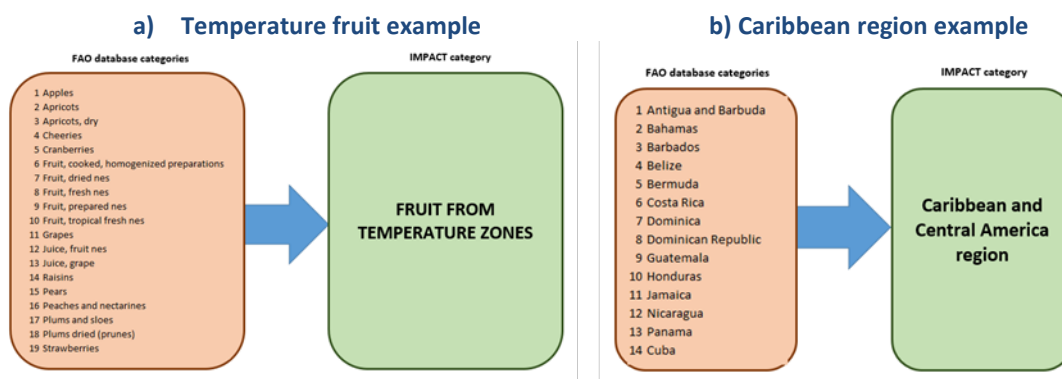
3.2 Mapping food and country categories

Mapping the many food import categories from historical data to the few food import categories that were modeled in IMPACT was an initial step in establishing food import patterns for the UAE. This was necessary because the "granularity" of the FAO detailed food trade matrices greatly exceeded that of the IMPACT model. That is, the FAO data track food trade for 322 food items, while not all of these are capable of being modeled in IMPACT. Altogether, there are 145 food types in the FAO food trade database that were mapped within a total of 40 major human food categories within the IMPACT model. As an example, annual import quantities for the 19 kinds of fruit from temperate zones of the world that are tracked in the FAO detailed trade matrix database were aggregated into the IMPACT category called "temperate fruit" (see Figure 4-1a), which is one of the 40 human food categories. The aggregated annual quantity was then the basis for subsequent macro-level modeling.

Mapping the countries that are tracked in the FAO detailed trade matrices to the country/region categories tracked in IMPACT was also required. Similar to food items, the

⁸ At the time of this writing, the FAO's detailed trade matrix was only available for the 2002-2008 period.

Figure 4-1: Mapping FAO food and country categories onto IMPACT food and country categories



granularity of the FAO detailed food trade matrices for countries exceeded that of the IMPACT model. That is, the FAO data track food trade for 169 countries, while climate change impacts as derived from IMPACT modeling results were available for only 115 countries/regions. All countries in the FAO database are accounted for in the IMPACT model at either the country or regional level. As an example, the 14 countries in the Caribbean and parts of Central America that are tracked in the FAO detailed trade matrix database were aggregated into the IMPACT category called “Caribbean and Central America” (see Figure 4-1b). The aggregated annual quantities at the regional level were then used in subsequent macro-level modeling.

3.3 Food import item modeling scope

The scope of food items considered in the analysis was less than the total number of food items imported to the UAE. The actual number of modeled food items was determined after an assessment of the types of food items annually imported to the UAE. That is, even though not all of the annually imported food items are addressed by the model, the 145 food items that can be modeled represent core types of food items on which the UAE’s food security depends. Of the 177 imported food items that are *not* modeled in IMPACT, 37 are inedible items (e.g., wool, tobacco, pet food, alfalfa); 9 items correspond to live animal imports (e.g., horses, cattle), and 6 items are processed foods (e.g., bread, pastry, cheese, breakfast cereals). While these items are imported in significant quantities to the UAE, they are of tangential significance to core issues regarding food security and were not considered in this study.

Figure 4-2: Shares of modeled and non-modeled imported food items, weight basis

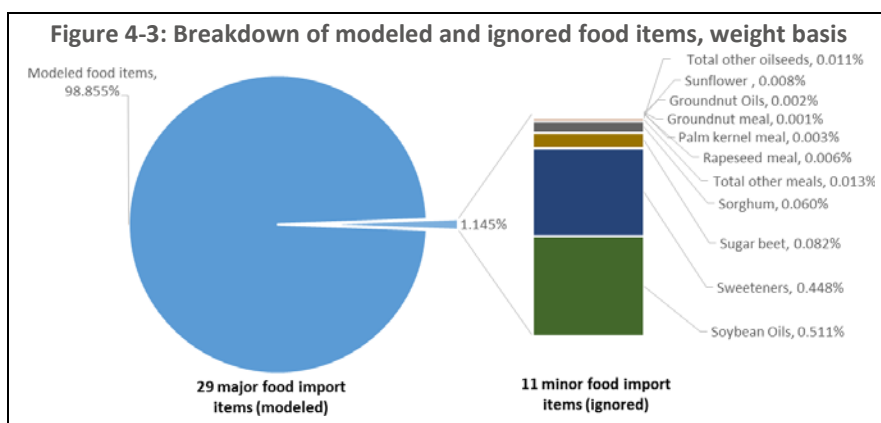


After netting out inedible, live, and processed items, the remaining 125 food items represent a comparatively small share of average annual imports to the UAE. This is

illustrated in Figure 4-2, which shows that while these food items account for 40% of the number of food items in the FAO database, they only represent about 12% of average annual imports to the UAE on a weight basis. On the other hand, the 145 modeled food items (i.e., 46% of all the imported food items in the FAO database) account for about 83% of average annual imports to the UAE on a weight basis.

One additional adjustment was made to establish the final scope of modeled food items.

The annual average import levels of some food items were so small that they could be ignored for practical purposes. That is, to streamline the analysis, those food items that account for a minimal share of average annual imports were ignored. This corresponded to a total of 11 food items out of the 40 major food items modeled in IMPACT. Combined, these 11 items typically account for only about 1.15% of average annual imports on a



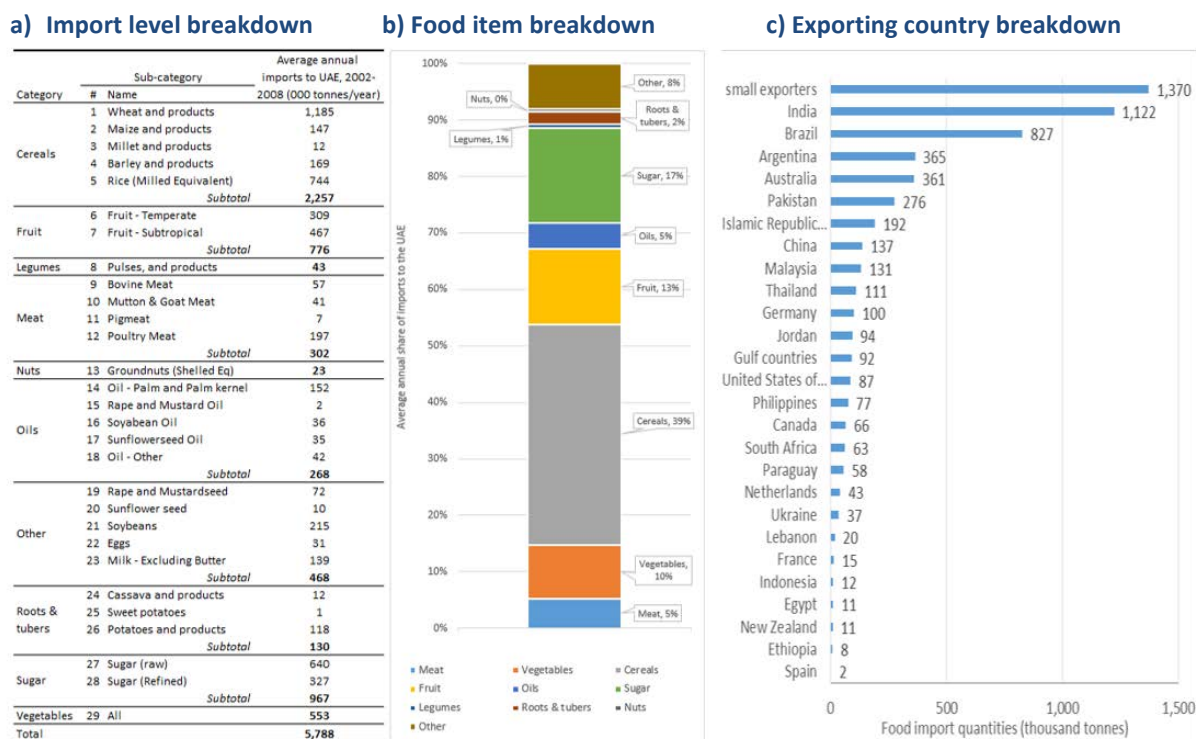
weight basis, as illustrated in Figure 4-3. Hence, for the purposes of this study, the food import modeling scope was set at 29 major food items. This coverage was considered adequate for characterizing food security at the macro level in the UAE.

3.4 UAE's food import profile

A summary of food imports to the UAE is shown in Figure 4-4 for the 29 major food items. Over the period 2002-2008, nearly 6 million tonnes per year were imported (Figure 4-4a). Cereals in the form of wheat, rice, and others accounted for the largest share of annual imports, 39%, followed by sugar at 17%, fruit from temperate and sub-tropical regions at 13%, vegetables at 10% and assorted meat products at 5% (Figure 4-4b). A total of 127 countries contributed to the UAE's food supply. Figure 4-4c shows a large variation across these countries, with India dominating average annual food imports and accounting for 1,122 thousand tonnes per year (21% of average annual levels). Other countries contributing large levels of annual food imports include Brazil, Argentina, Australia, Pakistan, and Iran which together provided about 2,021 thousand tonnes per year (35% of average annual levels). At the other end of the spectrum, a total of 101 countries each providing comparatively small levels of imports. However, when these levels are aggregated across all countries, import levels are relatively high, reaching 1,370 thousand tonnes per year (24% of average annual levels).

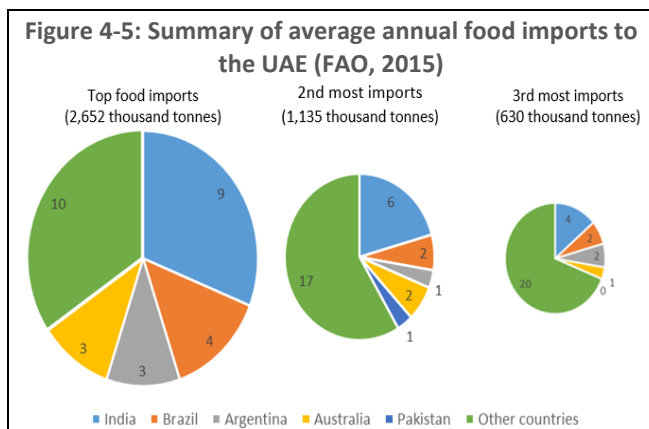
Major food exporters are fairly well distributed across the 29 modeled food items. That is, top food exporters to the UAE in terms of total tonnes also tend to be top exporters in terms of total food items. For example, India is the top exporter to the UAE for 9 of the 29 modeled

Figure 4-4: Summary of average annual food imports to the UAE (FAO, 2015)



food items; the second highest exporter for another 6 food items, and the third highest for 4 food items (see Figure 4-5). Altogether, India is one of the top three exporting countries for a total of 19 major food items. The next set of major exporting countries, Brazil and Argentina,

are among the top three exporting countries for 8 and 6 food items, respectively (see Figure 4-5). Other contributing countries to the UAE food supply profile increase in number from the first to the third import category. That is, other countries account for 10 of the 29 food items in the top food import category; 17 out of 29 food items in the second food import category; and 20 of 29 food items in the third food import category.



3.5 Major food-country combinations

The ultimate aim of establishing current food import supply patterns in the UAE is to better characterize the relative roles of food exporting countries to the UAE's food security. This serves as an essential point of departure against which to compare the potential future roles of these same countries after accounting for the impacts of climate change on the productivity of their agricultural sectors. For the purposes of subsequent analysis, a set of key "food-country combinations" was developed. These combinations were defined as the top 3 exporting countries in each of the modeled food import categories based on the highest average annual imports to the UAE over the 2002-2008 period. The total number of major food-country combinations is 87 (i.e., the product of 3 countries and 29 modeled food items). These combinations are summarized in Table 4-1 relative to average annual imports to the UAE over the 2002-2008 period.

The average annual share of food exports provided to the UAE from its major suppliers is small compared to the overall exports of these countries. That is, of the 87 major food-country combinations, most exhibit small shares of total exports that are sent to the UAE. This is illustrated in Figure 4-6 which shows that 52 food-country combinations represent under 1% of country exports. For example, average annual exports of cassava from India, the top exporting country, of 6 thousand tonnes (see Table 4-1) represent about 0.2% that total cassava production in India. At the other end of the spectrum, there are 8 food-country combinations that represent over 5% of country exports. An example is palm and palm kernel oil from Malaysia. Average annual exports to the UAE represent about 13.8% of total production in that country.

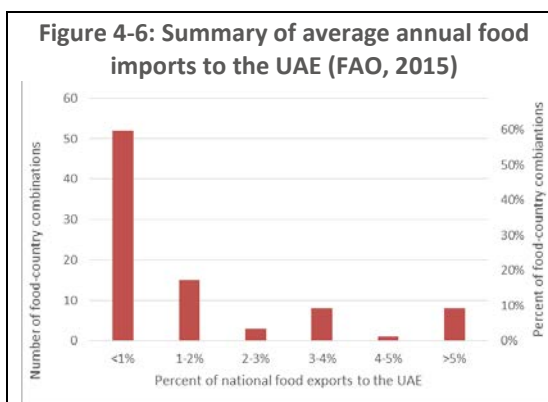
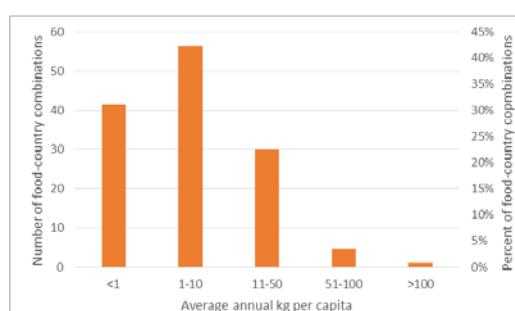


Table 4-1: Top 3 food-country combinations for exports to the UAE (FAO, 2015)

Modeled food item #	Major food item	Description	Top exporters to UAE			Average imports from top exporters to UAE over 2002-2008 (000 tonnes per year)				
			Country 1	Country 2	Country 3	Country 1	Country 2	Country 3	Others	Total
1	Cereals	Wheat and products	India	Australia	Argentina	409	225	155	397	1,185
2		Maize and products	Argentina	India	United States	88	29	21	9	147
3		Millet and products	India	China	Iran	10	1	0	0	12
4		Barley and products	Australia	Ukraine	India	104	26	16	23	169
5		Rice (Milled Equivalent)	India	Pakistan	Thailand	337	276	110	21	744
					Subtotal:	948	557	302	451	2,257
6	Fruit	Fruit - Temperate	Iran	India	China	66	37	30	175	309
7		Fruit - Subtropical	Iran	Philippines	South Africa	118	77	63	209	467
					Subtotal:	184	114	93	384	776
8	Legumes	Pulses, and products	India	Iran	Ethiopia	9	8	6	21	43
					Subtotal:	9	8	6	21	43
9	Meat	Bovine Meat	India	Brazil	Australia	28	12	4	14	57
10		Mutton & Goat Meat	Australia	India	Ethiopia	16	11	2	12	41
11		Pigmeat	Brazil	Netherlands	China	3	1	1	3	7
12		Poultry Meat	Brazil	United States	France	136	20	15	26	197
					Subtotal:	183	43	22	54	302
13	Nuts	Groundnuts (Shelled Eq)	China	India	Argentina	16	4	3	0	23
14		Oil - Palm and Palm kernel	Malaysia	Indonesia	China	131	12	0	9	152
15		Rape and Mustard Oil	Australia	Malaysia	India	1	0	0	1	2
16		Soyabean Oil	Brazil	Argentina	India	18	7	1	10	36
17		Sunflowerseed Oil	Argentina	Ukraine	Brazil	17	11	1	6	35
18		Oil - Other	United States	China	Spain	12	9	2	19	42
					Subtotal:	195	44	7	45	291
19	Other	Rape and Mustardseed	Canada	Australia	India	61	11	1	0	72
20		Sunflower seed	Canada	United States	China	6	2	1	2	10
21		Soybeans	Argentina	Paraguay	United States	95	58	32	30	215
22		Eggs	India	Brazil	Netherlands	15	4	3	9	31
23		Milk - Excluding Butter	Gulf countries	Netherlands	New Zealand	54	38	11	36	139
					Subtotal:	230	112	48	77	468
24	Roots & tubers	Cassava and products	India	Thailand	China	6	2	2	2	12
25		Sweet potatoes	India	Egypt	United States	0	0	0	0	1
26		Potatoes and products	Gulf countries	Lebanon	Egypt	38	20	10	50	118
					Subtotal:	44	22	12	52	130
27	Sugar	Sugar (raw)	Brazil	India	Egypt	591	47	0	2	640
28		Sugar (Refined)	Germany	India	Brazil	100	95	62	69	327
					Subtotal:	692	142	63	71	967
29	Vegetables	Vegetables - All	India	Jordan	China	167	94	77	215	553
					Subtotal:	167	94	77	215	553
Total						2,652	1,135	630	1,370	5,788

Imports per capita show different patterns at the food-country combination level. That is, of the 87 major food-country combinations, per capita food demand in the UAE is fairly evenly distributed below 50 kg per capita per year. Even after including the additional 29 food-country combinations for the remainder of food imports, this pattern is evident. This is illustrated in Figure 4-7 for the 116 food-country combinations (i.e., 87 combinations for the top 3 importing countries, plus an additional 29 combinations that address the remainder of annual imports). This Figure shows that a total of 36 food-country combinations are imported at levels below 1 kg/capita per year (31% of total); 49 food-country combinations between 1 and 10 kg/capita per year (42% of total), and 26 food-country combinations between 11 and 50 kg/capita per year 23% of total). Only 5 food combinations are in excess of 51 kg/capita per year (4% of total),

Figure 4-7: Summary of average annual food imports to the UAE, per capita basis, 2002-2008



Sources: FAO detailed food trade data combined with average historical population levels from the UN

4. IMPACT simulations

This section provides an overview of the approach used to establish the impacts of climate change on the agricultural productivity of major food-exporting countries for the UAE. The section begins with a brief overview of the overall approach. This is followed by a discussion of the core outputs of the IMPACT model. All the subsections below are offered as a high level summary of model results. The reader is kindly referred to the annexes of CCRG (2015c) for additional details and quantitative summaries associated with the outputs from IMPACT model runs.

4.1 Introductory remarks

The results of IMPACT model runs were used as the basis to project agricultural productivity of the UAE's major trading partners. A comprehensive set of model outputs was produced by colleagues at IFPRI, using the latest version of the model as of summer of 2014 (Nelson et al., 2010), and provided to the project team as a set of Excel pivot tables. The time period for the outputs was a 50-year period from 2000-2050. For the purposes of this study, the analysis focused on a portion of these results, from 2010 to 2050. IMPACT model run results correspond to two major scenarios, a "Baseline Scenario" that corresponds to business-as-usual agricultural productivity under a stable climate and a number of "Climate Impact Scenarios" that correspond to alternative agricultural productivity after accounting for the potential impacts of climate change. These projections were then incorporated into the EFFSeCC model databases.

4.2 Scenario development

Scenarios were used as a means of bracketing the uncertainties involved in estimating agricultural production in food exporting countries under climate change. Greenhouse gas (GHG) emissions, socioeconomic conditions, and global circulation models (GCM) were the primary bases for developing these scenarios. These are the major factors that are incorporated within the IMPACT model and which are primary drivers regarding future agricultural productivity and food trade prices. Each factor was explicitly addressed using a range of plausible low, mid, and high values.

Regarding future greenhouse gas emissions, there was no single emissions scenario that was considered as the most likely. The A1B and B1 emission forecasts from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) were used to represent upper and lower bounds of future emissions (See

Box 5-1: Emissions scenarios considered in the analysis (IPCC, 2007)

A1B. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The A1B scenario assumes a balance between fossil and non-fossil sources of energy.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies.

Box 5-1). Higher levels of global GHG emissions are projected under the A1B scenario; lower levels of global GHG emissions are projected under the B1 scenario.

Population and national GDP growth rates were used to characterize socioeconomic conditions. For the Baseline Scenario, GDP growth assumptions were based on rates from the World Bank (Margolis, et al., 2010), while population growth rates were assumed as the UN medium variant. For the Climate Impact Scenarios, GDP growth assumptions were based on the highest and lowest rates reported by the Millennium Ecosystem assessment, while population growth rates were assumed as the UN low and high variants.

For each emission scenario, two well-established global circulation models (GCM) were used to project future climatic conditions. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) GCM shows almost no increase in average annual precipitation and the smallest temperature increase of any GCM/emission scenario combination. The results of this model predict a drier planet with less of an increase in warming. The Model for Interdisciplinary Research on Climate (MIROC) GCM shows one of the largest increases in rainfall and average temperature. The results of this model predict a wetter planet with more of an increase in warming.

Table 5-1: Summary of scenario combinations (Nelson, et al., 2010)

#	Scenario Name	Future growth rate		Future climate		Drivers	
		GDP	Population	Rainfall	Temperature	GHG emissions	GCM
1	Base	Central	Central	Historical	Historical	High	NA
2	CSI_369_A1_med	Central	Central	Dry	Relatively cool	High	CSIRO
3	CSI_369_B1_med	Central	Central	Dry	Relatively cool	Low	CSIRO
4	MIR_369_A1_med	Central	Central	Wet	Relatively warm	High	MIROC
5	MIR_369_B1_med	Central	Central	Wet	Relatively warm	Low	MIROC
6	CSI_369_A1_opt	High	Low	Dry	Relatively cool	High	CSIRO
7	CSI_369_B1_opt	High	Low	Dry	Relatively cool	Low	CSIRO
8	MIR_369_A1_opt	High	Low	Wet	Relatively warm	High	MIROC
9	MIR_369_B1_opt	High	Low	Wet	Relatively warm	Low	MIROC
10	CSI_369_A1_pess	Low	High	Dry	Relatively cool	High	CSIRO
11	CSI_369_B1_pess	Low	High	Dry	Relatively cool	Low	CSIRO
12	MIR_369_A1_pess	Low	High	Wet	Relatively warm	High	MIROC
13	MIR_369_B1_pess	Low	High	Wet	Relatively warm	Low	MIROC

There are 13 scenarios considered in the analysis to account for the range of assumptions. A summary of the scenarios is provided in Table 5-1. IMPACT model run outputs regarding yield, national supply, prices correspond to each of these scenarios for the period 2000-2050. Future food imports to the UAE were evaluated relative to each of these scenarios.

4.3 Structure of IMPACT outputs

There are seven (7) key types of outputs associated with the IMPACT simulations under climate change. These are provided as large Excel pivot tables that report results for 115 countries/regions for the 29 major food items over the 2000-2050 period (IFPRIa) for each of the 13 scenarios. Table 5-2 provides structural summary of the contents in these tables. A brief overview of some of the key parameters included in these outputs tables is summarized in the bullets below.

- *Cultivated area.* These outputs show a projection of national crop harvest area by land type, in units of thousand hectares for irrigated and rain fed areas. Outputs are provided at both the national level and food production unit (FPU) level.⁹

⁹ FPU represents the spatial intersection of the 115 economic (mostly geo-political) countries/regions and the 126 water basins in these areas.

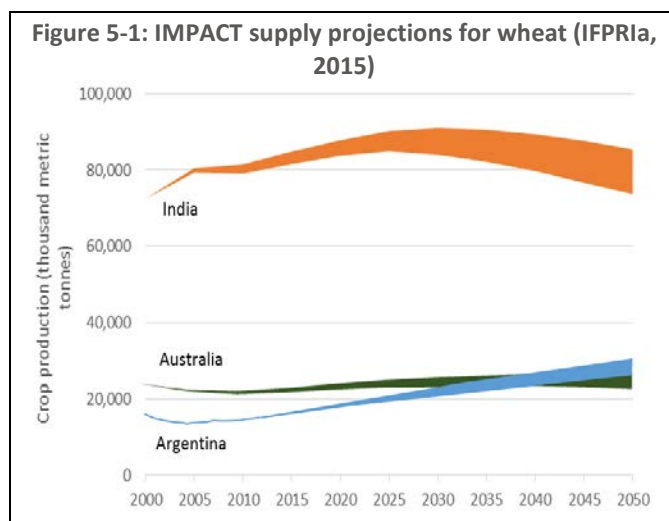
Table 5-2: Outputs of the IMPACT model (Nelson, et al., 2010)

Parameter	Output
Cultivated area	national crop harvest area by land type (000 ha)
	fpu crop harvest area by land type (000 ha)
	total national crop harvest area (000 ha)
	cultivar area over time for each simulation and <u>yiter</u> (000 ha)
	total cultivar area over time for each simulation and <u>yiter</u> (000 ha)
	cultivar area growth over time for each simulation and <u>yiter</u> (000 ha)
	total cultivar area by FPU over time for each simulation and <u>yiter</u> (000 ha)
	cultivar share of area over time and simulation (000 ha)
Food demand	national count of producing animals (000 animals) or <u>sweetner</u> area (000 ha)
	fpu count of producing animals (000 animals) by livestock production system
	food demand solved for <u>yiter</u> and sim (000 mt)
	urban food demand for <u>yiter</u> and sim (000 mt)
	rural food demand for <u>yiter</u> and sim (000 mt)
	feed demand solved for <u>yiter</u> and sim (000 mt)
	other demand solved for <u>yiter</u> and sim (000 mt)
	total biofuel demand by crop for <u>yiter</u> and sim (000 mt)
Socioeconomic & demographics	crush demand solved for <u>yiter</u> and sim (000 mt)
	total demand solved for <u>yiter</u> and sim (000 mt)
	national population (millions)
	Gross Domestic Product (billion constant 2000 US\$)
	per capita GDP (constant 2000 US\$/person)
	urban population solved for <u>yiter</u> and sim (millions)
	rural population solved for <u>yiter</u> and sim (millions)
	urban gdp solved for <u>yiter</u> and sim (billion constant 2000 US\$)
Prices	rural gdp solved for <u>yiter</u> and sim (billion constant 2000 US\$)
	World Price (constant 2000 US\$/mt)
	Country Trade Price (constant 2000 US\$/mt)
	Country Intermediate Price (constant 2000 US\$/mt)
	oil prices (constant 2000 US\$/mt)
	meal prices (constant 2000 US\$/mt)
	crush margin -- crush revenue to cost ratio -- overtime
	country producer price solved for <u>yiter</u> and sim (constant 2000 US\$/mt)
Supply	country consumer price solved for <u>yiter</u> and sim (constant 2000 US\$/mt)
	total national commodity production (000 mt)
	total fpu commodity production (000 mt)
	national commodity production by land type (000 mt)
	fpu commodity production by land type (000 mt)
	cultivar production by FPU over time for each land type for each simulation and <u>yiter</u> (000 mt)
	total cultivar production by FPU over time for each land type for each simulation and <u>yiter</u> (000 mt)
	total cultivar production by FPU over time for each simulation and <u>yiter</u> (000 mt)
Welfare	net trade (000 mt): negative=imports, positive=exports
	stock change solved for <u>yiter</u> and sim (000 mt)
	share of total calories from each commodity for <u>yiter</u> and sim (Kcal)
	per capita calories available for <u>yiter</u> and sim (Kcal/person/day)
	total calories available for <u>yiter</u> and sim (Kcal/day)
	percent of children malnourished for <u>yiter</u> and sim (%)
	total malnourished children for <u>yiter</u> and sim (millions)
	the ratio of available kcal over minimum kcal
Yield	share of population at risk of hunger (%)
	population at risk of hunger (millions)
	National Livestock Yield (kg/animal)
	FPU Livestock Yield by livestock production system (kg/animal)
	FPU Crop Yield by land (mt/ha)
	National Crop Yield by land type (mt/ha)
	cultivar yield over time for each simulation and <u>yiter</u> (kg/ha)
	cultivar yield growth over time for each simulation and <u>yiter</u> (kg/ha)
	Total FPU Crop Yield (mt/ha)
	Total National Crop Yield (mt/ha)
	total <u>cultivar</u> yield over time for each simulation and <u>yiter</u> (kg/ha)
	total cultivar yield by FPU over time for each simulation and <u>yiter</u> (kg/ha)

- *Food demand.* These outputs represent a projection of food demand, in units of thousand metric tonnes, for rural and urban areas. Outputs are provided at the national level. Also included is a projection of feed and biofuel demand, in units of thousand metric tonnes, at the national level.
- *Socioeconomic and demographics.* These outputs contain a projection of key socioeconomic factors at the national level such as population, GDP, per capita GDP, urban/rural population, and urban/rural GDP.
- *Prices.* These outputs contain a projection of world prices (real \$) per food commodity as well as a projection of country-level food trade prices. Also included are projections of producer prices and consumer prices by country.
- *Food supply.* These outputs show a projection of national food commodity production, in units of thousand metric tonnes, for the national level and food production unit (FPU) level. Outputs are provided for both irrigated and rain fed areas.
- *Welfare.* These outputs contain a projection of a number of national indicators such as the share of population at risk from hunger, ratio of available diets to minimum acceptable diets, and percent of malnourished children.
- *Agricultural yield.* These outputs contain a projection of national livestock yield, in units of kg per animal, as well as a projection of crop yield in units of metric tonnes per hectare. Outputs are provided for both irrigated and rain fed areas as well as a national and FPU scales.

4.4 Food supply outputs

The food supply projections are central to the subsequent characterization of macro-level food security. The IMPACT results show that there can be large differences in productivity across food items and countries, relative to time and climate change scenario. As an illustration, Figure 5-1 shows the range in future productivity across the 13 scenarios of the UAE's most intensive food import, wheat, for the top three countries from where this food item has been historically imported.



Each of the country curves for wheat shows a number of distinct features relative to the impact of climate change. For India, there is a large uncertainty band between minimum and maximum productivity levels (i.e., around 12 million tonnes per year by 2050). Australia and

Argentina, on the other hand, show a smaller range of uncertainty (i.e., around 4 million tonnes per year by 2050) although this range represents a larger share compared to minimum future production levels in that year. Also noteworthy is the projected impact of climate change on the agricultural productivity in each country. For India, climate change manifests itself by an eventual and significant decline in productivity over time; Australia shows mostly flat agricultural productivity, while productivity in Argentina shows the opposite trend, growing somewhere between 67 and 94% over the period, indicating that Argentina is one of those countries where climate change is projected to have positive impacts. Similar observations are evident for the productivity characteristics of the 28 other modeled food items.

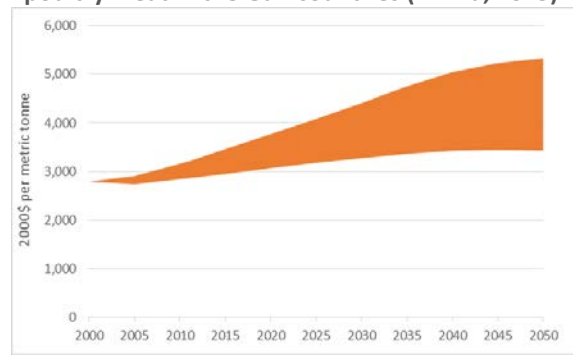
4.5 Consumer food prices

The consumer food price projections are central to the subsequent characterization of micro-level food security. The IMPACT results show that there can be large differences in the projected consumer price for a given food item in the Gulf countries, relative to time and climate change scenario. As an illustration, Figure 5-2 shows the range in future consumer prices, as reported in real 2000\$, in the Gulf countries across the 13 scenarios for the UAE's most intensive meat import, poultry.

The price projection for poultry shows several notable features relative to the impact of climate change. First, there is a large uncertainty band between minimum and maximum consumer price in the Gulf (i.e., around \$1,900 per tonne by 2050).

This is over half of the minimum price in that year, indicating a high level of uncertainty. Also noteworthy is the fact that real consumer prices for poultry increase in all scenarios, ranging from a minimum 22% to a maximum of 91%. Similar observations are evident for the productivity characteristics of the 28 other modeled food items.

Figure 5-2: IMPACT consumer price projections for poultry meat in the Gulf countries (IFPRIa, 2015)



5. UAE socioeconomic characteristics

This section provides an overview of the approach used to establish socioeconomic trends in the UAE. The focus is on broad national trends in population, as well as more detailed trends in income and expenditure at the household level. The section begins with a brief overview of the overall sources of information. This is followed by a discussion of a number of key national trends that affect the vulnerability of UAE household to food price increases, including typical spending on food and food price inflation relative to other commodities. This is followed by a discussion of some key characteristics such as gross per capita income, disposable per household income and household expenditure shares of discretionary and non-discretionary items. This section ends with a summary of population projections. To the extent possible, the subsections below offer disaggregated trends by emirate and income levels.

5.1 Introductory remarks

Characterizing key socioeconomic characteristics for the UAE focused on four major areas. Supporting data was obtained from several sources and covered the recent historical period. Where necessary, data was obtained for the future period through 2030, as possible. A brief overview is offered in the bullets below. This information was then incorporated into the EFFSeCC model databases.

- *Consumer price index.* Time series data used for developing the UAE's consumer price indices and other socioeconomic information were obtained from the website of the UAE's National Bureau of Statistics (NSB). This included disaggregated data by emirate as well as type of commodity (NSB, 2015).
- *Household income and expenditures.* Much of the household income and expenditure data discussed below is based on the results of Abu Dhabi's Household Income & Expenditure Survey, carried out in 2007 and 2008 (SCAD, 2014). This information was augmented by the Passport Income and Expenditure report for the UAE developed by Euromonitor International (Euromonitor International, 2015).¹⁰ This report synthesizes the major current trends in UAE incomes and expenditures based on the sources noted above, and provides a set of projections for income and expenditures through 2030.
- *National food expenditures.* Time series data regarding historical food expenditure trends for the UAE and other countries were obtained from publicly available databases maintained by the US Department of Agriculture (USDA, 2015). This data provided an estimate of the share of household disposable income spent on food for the recent historical period (i.e., 2011 through 2014).

¹⁰ Passport is a commercial global market research database that offers statistics and analysis on 210 countries and consumer groups within those countries. The databases have been used by planning agencies around the world, including the US Department of Agriculture (USDA) which relies on Passport data for its own food expenditure database. More information is available at <http://www.euromonitor.com/>

- *Population and infrastructure.* Planning documents that establish resource and development plans to 2030 at both the emirate (e.g., Abu Dhabi Vision 2030) and national level (e.g., UAE Green Growth Strategy) provided a basis for establishing development and growth priorities. Population characteristics were based on data from the NSB for the historical period (i.e., 2006-2010) and the UN for national population projections (i.e., 2010-2050).

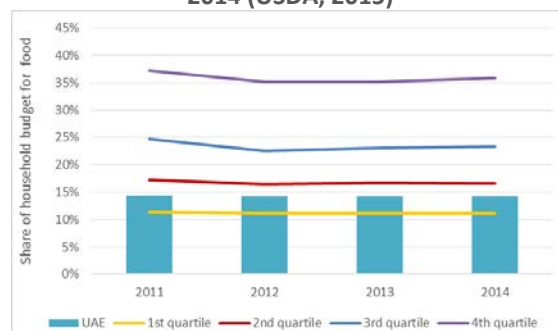
5.2 Food expenditure trends

Food expenditures refers to the amount that households devote to food purchases as a share of total expenditures. Household spending can be divided into discretionary and non-discretionary categories, both of which are relative to disposable income.¹¹ A discretionary household expense is a cost which is not essential for the operation of a home such as purchases for recreational/cultural activities, alcoholic beverages, tobacco products, restaurants/cafes, etc. On the other hand, non-discretionary household expenses are those are essential for the operation of a home, namely food, housing, and healthcare. Typically, these items are considered the highest priorities in a household budget and are purchased at the expense of the range of non-discretionary items.

At the national level, the share of household budgets spent on food is influenced by many socio-economic factors, chief among them being food prices and household income levels.

Figure 6-1 shows average annual share of household budgets spent on food for the period 2011-2014 (USDA, 2015). The data correspond to 86 countries for which data were available for the entire time period. For the purpose of comparisons, these countries were divided into quartiles defined by total annual household expenditures. In the 1st quartile (i.e., highest household outlays), total annual household expenditures ranged from \$19.1 (Spain) to \$46.6 (Switzerland) thousand; in the 4th quartile (i.e., lowest household outlays), total annual household expenditures ranged from \$0.7 (Kenya) to \$3.0 (Thailand). As can be seen in the Figure, household food expenditure shares in the UAE are closer to the countries in the 1st quartile. Across the seven emirates in the UAE, household food expenditure shares have been relatively stable in recent years, ranging from 14.4% in 2011 to about 14.2% in 2014. A smaller share of household budgets are spent on food by households in the countries of the 1st quartile, ranging from an average of 11.3% in 2011 to about 11.1% in 2014.

Figure 6-1: Food expenditures as a share of household expenditure at the national level, 2011-2014 (USDA, 2015)



¹¹ Disposable income is defined as the amount of money that households have available for discretionary and non-discretionary spending and saving after all income taxes have been accounted for.

National food expenditure trends are broadly consistent with the results of affordability, access and stability food security indicators discussed earlier. That is, those data indicated that the UAE as a whole compared well with the countries included in the “developed” country category, which are generally acknowledged to be more food-secure. Households that spent a larger share of their budgets on a non-discretionary item like food are more vulnerable to food price shocks under climate change, a situation that prevails for the 4th quartile. Households in these countries averaged annual food budget shares that were 37.2% in 2011 and 35.8% in 2014, at least twice the level of food expenditure shares when compared to countries in the first and second quartiles.

5.3 Food price trends

UAE households have among the highest disposable incomes in the world within an economy that has been growing rapidly. However, across the UAE there is a high degree of household income stratification and corresponding differences in the share of expenditures on a range of household items, including food. Moreover, price trends for all items have been increasing due to rising inflation levels. These rising prices have had the effect of eroding purchasing power to various degrees, depending on the emirate.

The Consumer Price Index (CPI) is a useful metric for exploring price trends and their impact at the emirate level.

The CPI enables a direct comparison of the prices that consumers pay for food relative to other commodities in the economy. Essentially, the CPI is an economic indicator that measures the weighted average of prices of a “basket” of consumer goods and services, including food (see Table 6-1). It is calculated by taking price changes for each item in the predetermined basket of goods and averaging them using a weighting systems that reflects their importance. Inflation is measured by the changes in the CPI from year to year (or from month to month). In the UAE, the CPI is calculated by the NSB and reported every month at both the UAE and emirate level.

Table 6-1: Items included in the measurement of the UAE’s CPI (NSB, 2014)

- Food and Soft Drinks
- Education
- Furniture and Household Goods
- Housing
- Beverages and Tobacco
- Miscellaneous Goods and Services
- Transportation
- Restaurants and Hotels
- Recreational and Cultural
- Communications
- Medical Care
- Textiles, Clothing and Footwear

At the national level, the CPI has been rising steadily over the past several years (See Figure 6-2). In particular, food prices (dashed green line) have been rising across the UAE more rapidly than the overall CPI (thick black line). Of particular note is the fact that food prices have been rising across the UAE more rapidly than all other individual commodity prices, except for tobacco and education. In fact, since 2008, food price inflation in the UAE has risen at about 2.2 times the average annual rate of overall inflation. The practical impact of this trend at the household level is that families across the UAE find themselves in the position of either devoting a larger share of household income to food purchases or adjusting spending habits to accommodate the higher food prices.

Similar trends for CPI are evident at the emirate level. Figure 6-3a illustrates the range in the CPI across the seven emirates for the same period 2008-2014. The gold-shaded area represents the range in CPI for food at the emirate level, with the blue line representing the UAE average of the food CPI. The brown-shaded area represents the range in CPI for all items at the emirate level, with the green line representing the UAE average of all items in the CPI. The curves show that there is both a larger variation in the food CPI than there is for the overall CPI, as well as steeper increases in the food CPI compared to the overall CPI.

According to the official statistics plotted in

Figure 6-3a, there are several noticeable food price spikes and declines during this period. The sharpest of these occurred in Ajman. The food price spike in the middle of 2008 corresponds to about a 19% hike in food prices that took place in a single month (July). The sharp decline in food CPI in late 2010 corresponds to a 20% drop in food prices for two months (October and November), then as rapid an increase in the month that followed with typical increases in food prices from that point onward. It is unclear the causes behind these food price fluctuations.

On an aggregate basis, some emirates are experiencing greater impact of rising food prices than others. Figure 6-3b shows that the rate of growth of the food CPI relative to the overall CPI for each emirate, as well the UAE as a whole. For the UAE, food prices have been increasing about 2.2 times the rate of overall prices. Four of the emirates are at or below this level (i.e., Abu Dhabi, Dubai, Ajman, and Fujairah). For the remaining emirate of Umm Al-Quwain, Ras Al-Khaimah, and Sharjah, food prices have been increasing at a higher rate than

Figure 6-2: Consumer Price Index trends at the national level, 2008-2014 (NSB, 2015)

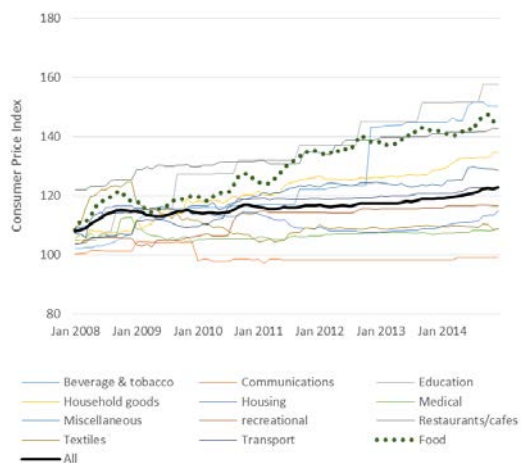
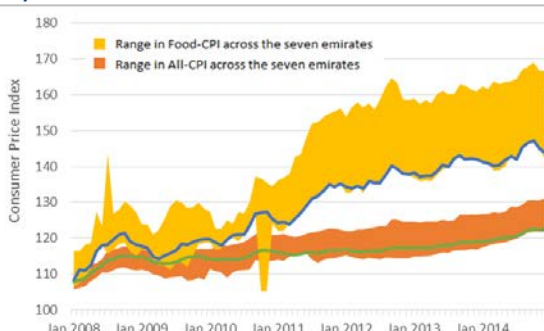
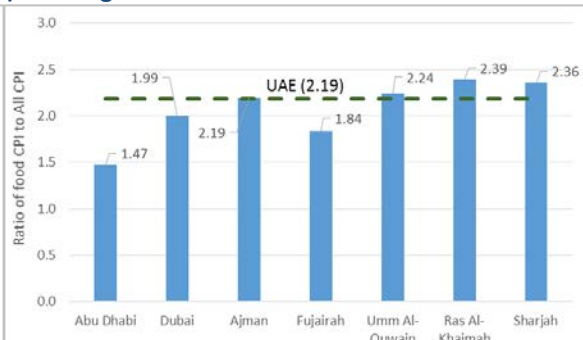


Figure 6-3: Consumer Price Index trends at the emirate level, 2008-2014 (NSB, 2015)

a) Annual CPI trends for Food and All items

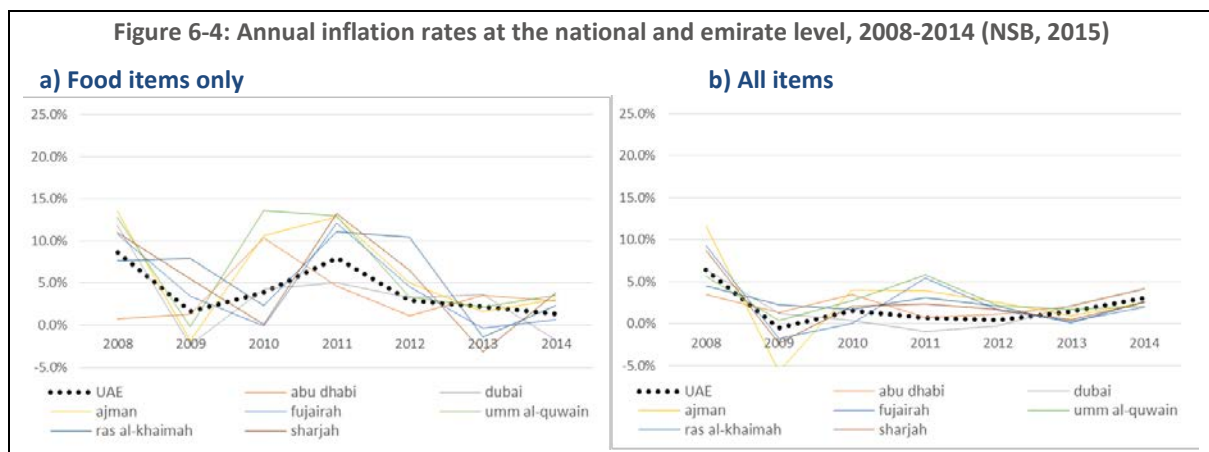


b) Overall growth in the ratio of Food- to All- CPI



the national average. This trend indicates that households in these emirates are likely facing stiffer challenges in coping with food price increases than their counterparts in the other emirates.

Annual CPI trends indicate that food price inflation is more volatile than overall inflation levels (see Figure 6-4). Inflation is defined as an increase in prices and fall in the purchasing value of money. It is calculated as the percent change in the CPI from month to month or year to year. At the national level, the annual inflation rate for food over the past six years is roughly twice the overall inflation rate. At the emirate level, the inflation rate for food relative to all items is lowest in Abu Dhabi (about 1.5 times higher) and highest in Umm Al-Quwain (about 2.3 times higher). Moreover, the inter-annual volatility in food prices is very evident at the emirate level, where food inflation was over 3 times the overall inflation level in Ajman in 2011 and nearly 11 times the overall inflation level in Dubai in 2010. However, there are years in certain emirates where the annual food inflation rate dips below the annual overall inflation rate. For example, this was the case in Sharjah in 2010 where food inflation was nearly zero while overall inflation reached 2.1%, as well as in Fujairah in 2014 where annual food inflation levels were a third less than overall inflation levels in that emirate.



5.4 Gross income trends

On a per capita basis, residents and citizens of the enjoy some of the highest gross incomes in the world. In 2014, the UAE's per capita average annual gross income was AED133,324 (US\$36,303)¹², the highest level among the Arabian Gulf countries. This was up from AED97,104 (US\$26,440) in 2009, which at that time was also the highest growth rate in the region. Between 2015 and 2030, per capita annual gross income is projected to rise by an average of 2.7% per year in real terms to finish the period at AED203,409 (US\$55,387).

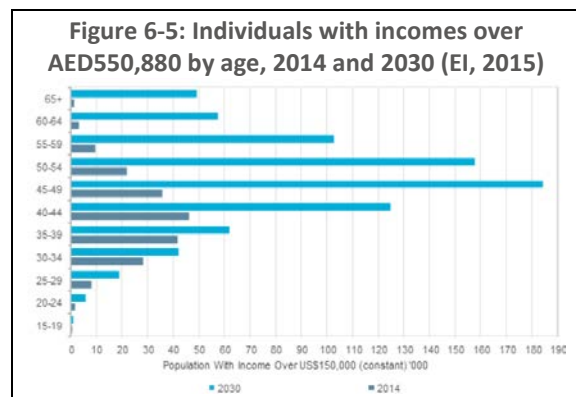
Income is strongly correlated with age in the UAE. Middle-aged individuals are prominent in the UAE's uppermost gross income bracket. The 40-44 age range made up the largest share of the population earning an annual gross income in excess of AED550,880 (US\$150,000+) in

¹² An exchange rate of AED3.67 for US\$ is assumed here and in the remainder of this report.

2014, at 23%, ahead of the 35-39 age bracket at 21%. This is partly a matter of demographics, as these two age bands accounted for a combined 29% of the UAE population at large in 2014. Most of the well-remunerated specialist expatriates working in the country fall into these middle-aged age ranges.

In the future, the ages showing the highest levels of income will shift somewhat to an older age bracket. In 2030, about 23% of individuals with an annual gross income of at least AED550,880 (US\$150,000) will be in the 45-49 age range, with the 50-54 age bracket second with 19.6% of individuals having that annual gross income level. Moreover, individuals aged 45-54 will account for about 30% of the total population. This shift in income brackets with age between 2014 and 2030 is illustrated in Figure 6-5.

The UAE population is characterized by large income differences between groups. In 2014, the UAE was home to about 7.5 million foreign citizens, many of whom are low paid migrant workers, usually from the Indian subcontinent, who hold jobs in construction or domestic service and remit most of their wages to families back home. Most of these individuals tend to fall in the lowest income category and make up about 31% of the population of individuals over 15 years of age. On the other hand, roughly 40% of the population were those pursuing careers or starting families, between 27 and 38, and having an average annual income between AED88,141 (US\$24,000) and AED238,715 (US\$65,000). This group consists mainly of Emirati professionals and expatriate specialists.



For the purpose of assessing the UAE population relative to the potential future impact of high food prices, income levels represent a useful basis for comparisons. Specifically, the following five income groups were considered to compare gross income levels:

- **Group 1:** Individuals with a gross income less than 50.0% of the average gross income of all individuals aged 15 and over. This group accounts for about 31% of the population.
- **Group 2:** Individuals with a gross income between 50.0% and 100% of the average gross income of all individuals aged 15 and over. This group accounts for about 32% of the population.
- **Group 3:** Individuals with a gross income between 100% and 150% of the average gross income of all individuals aged 15 and over. It was assumed that this group accounts for about 18% of the population.
- **Group 4:** Individuals with a gross income between 150% and 200% of the average gross income of all individuals aged 15 and over. It was assumed that this group accounts for about 12% of the population.

- **Group5:** Individuals with a gross income over 200% of the average gross income of all individuals aged 15 and over. It was assumed that this group accounts for about 7% of the population.

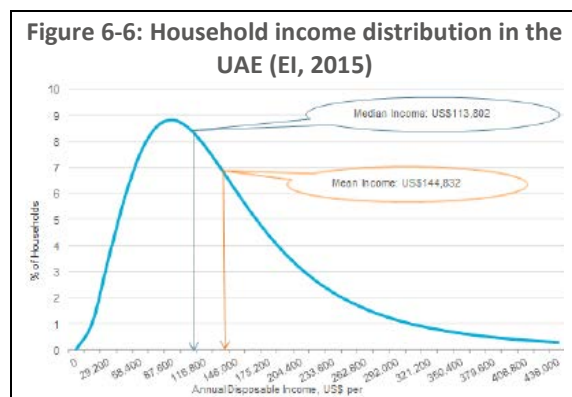
Over the recent 2009-2014 period, the lowest (Group 1) and highest (Group 5) income groups experienced the fastest expansion in population, roughly 14% and 13%, respectively. This same trends is expected to continue through 2030. Between 2014 and 2030 the population of the lowest income group is expected to increase by about 44% while the population of the highest income group is expected to increase by about 40%. This in contrast to the middle-income groups (i.e., Groups 2, 3, and 4) whose population grew considerably more slowly during 2009-2014, showing an increase in population for each group less than about 5%. In the future, the population of these groups is projected to expand by less than 20%.

By 2030, the population of the lowest income group (Group 1) is projected to overtake Group 2 as having the largest population in the UAE. By 2030, Group 1 is expected to comprise about 36% of the population that is over 15 years of age. Most of the people in this income category will likely be in late middle age, with rough 30% being between the ages of 45 and 54. It is reasonable to assume that the demand for social services for this group will increase proportional to their increase in population.

5.5 Household disposable income trends

In 2014, there were about 1.7 million households in the UAE, with a little over 5 persons per household. UAE households enjoy some of the highest disposable incomes in the world. Disposable incomes at the household level are key to developing food security indicators because these are the actual resources available for expenditures on food. In 2014, the UAE's per household average annual disposable income was AED531,896 (US\$144,832), also the highest level among the Arabian Gulf countries, while the median household income (i.e., the income level that evenly divides total number of households in the UAE) was AED417,938 (US\$113,802). Roughly 35% of all households in the UAE had higher levels of disposable income relative to average household income levels, with a higher share relative to the median household income level (see Figure 6-6).

For the purpose of assessing UAE households relative to the potential future impact of high food prices, breaking out households into decile represents a useful basis for comparisons. Specifically, 10 income groups (i.e., deciles) were considered to compare household disposable income levels. The poorest households are included in Decile 1 and the most affluent in Decile 10. In 2014, total annual disposable income levels showed large difference between these two groups. The



least affluent households in Decile 1 showed an annual average income of AED106,448 (US\$29,005), equivalent to about 2.0% of total annual disposable income. The most affluent households in Decile 10 showed an annual average income of AED1,573,733 (US\$428,810), equivalent to about 29.1% of total annual disposable income. Middle class households in Decile 5 showed an annual average income of AED381,449 (US\$103,937), equivalent to about 7.1% of total annual disposable income.

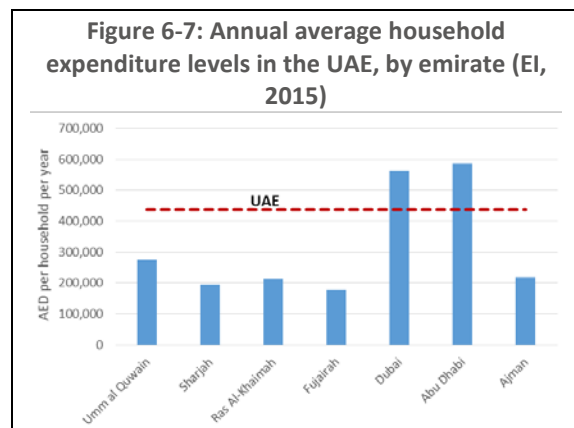
Recent data as well as future projections show household incomes rising in the UAE. In 2009, the average household income were AED402,952 (US\$109,720). By 2014, this had increased by about 32% to AED531,896 (US\$144,832), or roughly a 5.7% per year. Between 2015 and 2030, per household average annual disposable income is projected to rise by about 44%, or an average of 2.5% per year in real terms, to reach AED766,462 (US\$208,701) by 2030. Over the same period, median household income levels are projected to rise about 41.5% in real terms, or about 2.3% per year. At the decile level over the 2014-2030 period, the shares of total annual disposable income are expected to remain fairly stable, with the share of the least affluent decreasing from 2.0% to about 1.9% and the share of the most affluent increasing from 29.1% to about 30.6%.

5.6 Household expenditure trends

At the emirate level, households in each of the seven emirates show significant variations in spending patterns. In 2014, the Abu Dhabi and Dubai emirates showed the highest average annual household spending levels at AED586,316 per year per household (US\$159,759) and AED561,591 (US\$153,022) per year per household, respectively. All other emirates show annual average expenditure levels at less than half the Dubai level (see Figure 6-7).

At the individual household level, variations in overall spending patterns are even more pronounced. In 2014, the least affluent households (i.e., Decile 1 as described in the previous subsection) throughout the UAE typically devoted nearly 70% of their overall 2014 expenditures to non-discretionary purchases (i.e., necessities like food, housing, and healthcare). For middle-income households (Decile 5), the figure was about 60% and for the most affluent households (i.e., Decile 10), less than half (46%) of their disposable income was spent on non-discretionary items. Over the 2014-2030 time period, these levels are expected to be stable, with negligible declines in each Decile.

Regarding households expenditures on food, the variations across income groups are similarly evident. This is illustrated in Figure 6-8 for the year 2014. As shown in the figure, the least affluent households throughout the UAE's seven emirates (i.e., Decile 1 as described in the previous subsection) typically devoted nearly 40% of their overall 2014 expenditures to

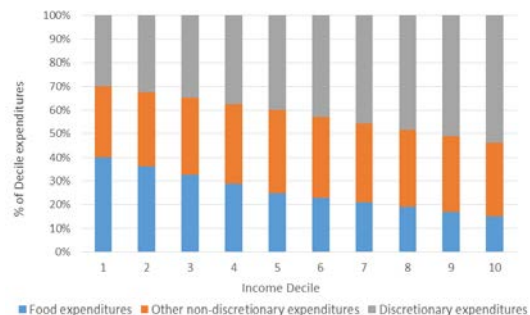


food, with only about 30% available for discretionary spending. For middle-income households (Decile 5), food expenditures accounted for about 25% of total spending, with about 40% available for discretionary purchases. For the most affluent households (i.e., Decile 10), only about 15% of their disposable income was spent on non-discretionary items, leaving over 50% available for discretionary purchases.

Over the 2014-2030 time period, these levels are expected to remain fairly stable, with negligible declines in each Decile. It is

important to note that these are projections under a baseline climate scenario that do not factor in the impacts of climate change. In a climate-changed future in the countries from which the UAE imports its food, there may be adverse impacts on agricultural productivity with an accompanying pressure on consumer food prices to rise. This situation can be expected to affect the shares of non-discretionary spending on food in future years. The extent to which food spending shares are impacted by climate change is a measure of household level vulnerability, as discussed in the micro-modeling and vulnerability indicator sections.

Figure 6-8: Household expenditure share levels by income group in the UAE (EI, 2015)



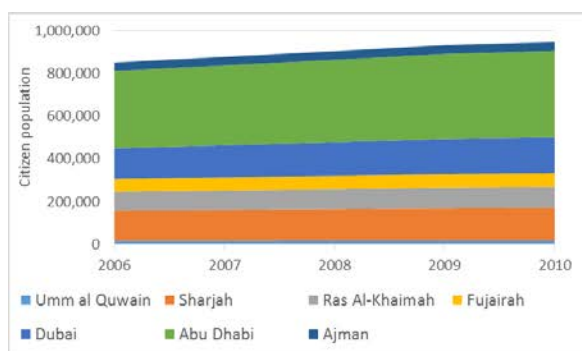
Note: Household expenditure shares for other than Deciles 1, 5, and 10 are interpolated

5.7 Population trends

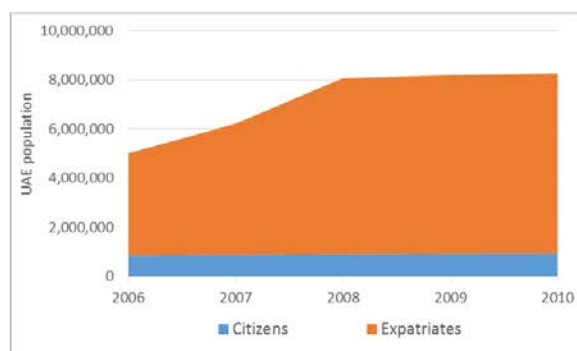
Population trends over the past five years show several notable features. First, population of citizens has been growing at an average annual rate of 2.7% per year over the period 2006-2010. The highest growth rate was in Dubai whose national population grew at 3.9% per year; the lowest growth rate was in Ajman whose national population grew at 1.4% per year. Total national population reached nearly 1 million in 2010 (see Figure 6-9a). Second, population growth among expatriates has been growing rapidly, 15.2% per year over the period 2006-

Figure 6-9: Population trends in the UAE, 2006-2010 (NSB, 2015)

a) Citizens population



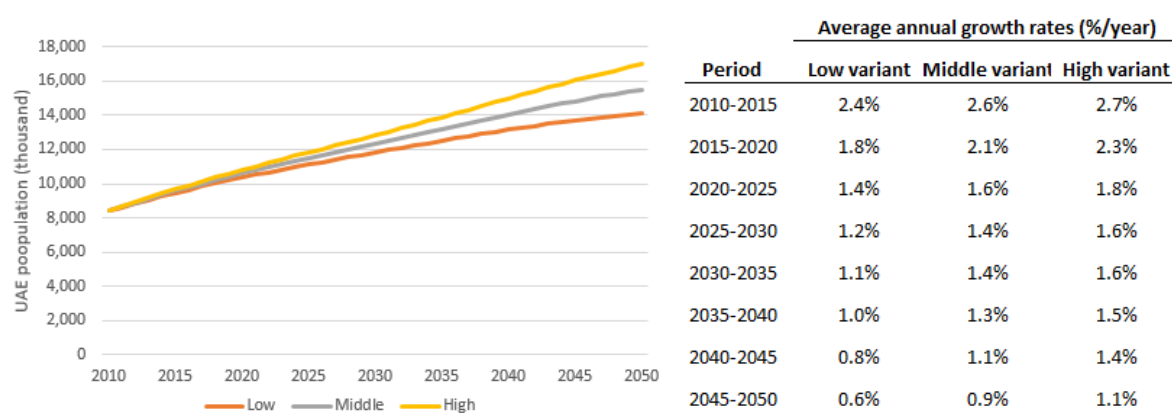
b) Citizen and expatriate population



2010. When combined with the citizen population, total population in the UAE reached just over 8 million in 2010 (see Figure 6-9b).

Projections of future population in the UAE have been obtained from the Population Division of the UN's Department of Economic and Social Affairs (UN, 2012). In order to bracket uncertainty, three projections were considered, namely middle, low and high population variants, for the period 2010 through 2050. The UN projections show declining growth rates over time with a total population in 2050 ranging from 14.1 million in the low variant to 17.0 in the high variant (see Figure 6-10).

Figure 6-10: Population projections for the UAE (UN, 2012)



6. Macro-level modeling

This section provides an overview of the macro-modeling approach used to produce the range of outputs needed for determining the food security of the UAE under climate change. As discussed earlier, “macro level” modeling refers to an assessment of the UAE’s future food security under climate as viewed through a national-level perspective. The section begins with a brief overview of the overall approach. This is followed by a discussion of how future food demand, available exports, and supply/demand comparison metrics were quantified.

6.1 Introductory remarks

The information in this section describes the modeling approach that was used to integrate food supply and demand under climate change. Macro-level modeling aimed to integrate all of the food import data from the FAO’s trade matrices and IMPACT food supply outputs for the specific countries on which the UAE has traditionally relied for food imports. A planning period of 2010 to 2050 was used. Three key parameters were the focus of macro-modeling, namely projecting future food demand in the UAE, projecting available future food exports to the UAE from top exporting countries, and calculating any food import gaps from a comparison of supply and demand under climate change. The sequence of calculations involved in the estimation of these parameters was codified in the EFFSeCC model to enable exploring sensitivities regarding key assumptions.

6.2 Future food demand

Future food imports to the UAE were projected on the basis of three key assumptions. First, it was assumed that the historical trends of the UAE population would continue into the future. This assumption is primarily focused on the composition of the population relative to the share of expatriates, with a similar share of the expatriate population relative to the total. Second, it was assumed that historical trends in the types and quantities of food consumed by the UAE population would continue into the future. This assumption is primarily focused on the diets of the UAE’s diverse population, with future diets being similar to past diets, and relied on the quantified average annual food intake per capita estimates. Third, it was assumed that there would be no national policy measures implemented that would significantly increase the share of food requirements met by agricultural production in the UAE. This assumption is primarily focused on the shares of future food requirements coming from imports, with future levels being consistent with past levels.

On the basis of the above assumptions, future imports for each of the 29 modeled food items were projected for each of the top exporting countries in the UAE’s food supply profile. To bracket uncertainty, projections were developed for each of the population variants, low, middle, and high presented in the previous section. The formula used for project annual food imports to the UAE is provided below:

$$I_{i,j,k,t} = \sum_{i=1}^{29} (D_{i,j} * P_{k,t})$$

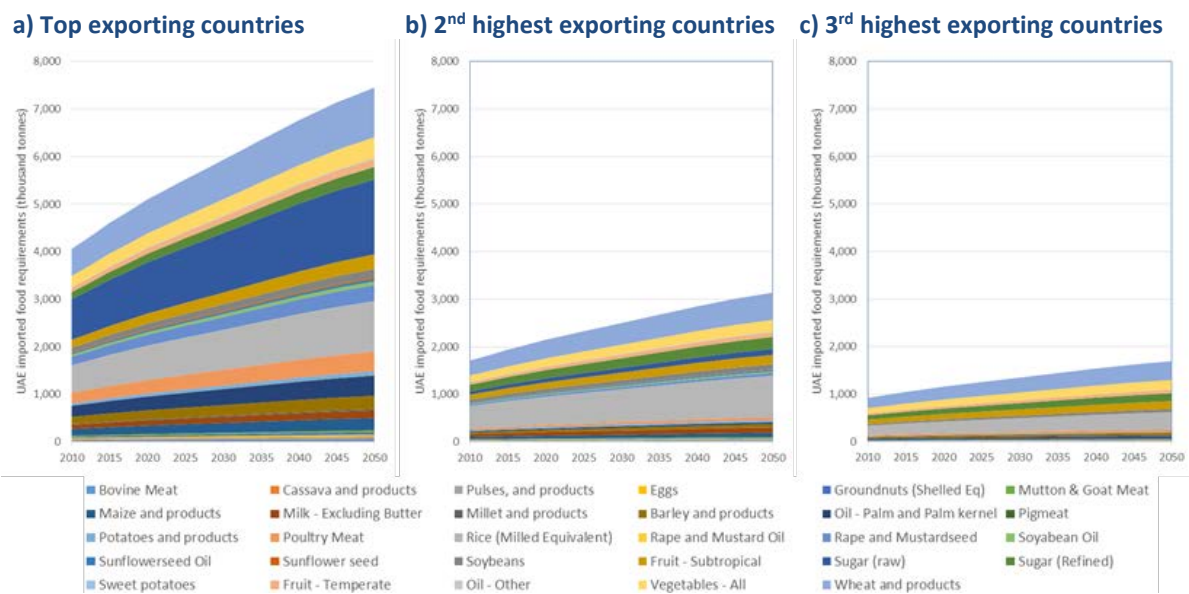
Where:

$I_{i,j,k,t}$ = Imported food quantity (000 tonnes) for food item i, from exporting country j, for population variant k, in year t

$D_{i,j}$ = Demand for food imports (kg/cap) for food item i from exporting country j

$P_{k,t}$ = UAE population for variant k in year t

Figure 7-1: Projected imported food requirements for the UAE for top historical exporters, 2010-2050; middle population variant



Detailed import projections were developed for each major food-country combination. The result was a series of projections that quantified the magnitude of imports by food item, by category of food exporter, by population projection variant. Figure 7-1 shows an illustrative set of the results for the middle population variant. Overall, food imports to the UAE are projected to increase by 83% over the period 2010-2050. Imports from the top exporting countries are projected to increase from 4.1 to 7.5 million tonnes across all modeled food items. Imports from the 2nd highest exporting countries are projected to increase from 1.7 to 3.1 million tonnes across all modeled food items. Imports from the 3rd highest exporting countries are projected to increase from 0.9 to 1.7 million tonnes across all modeled food items. Imports from all remaining countries are projected to increase from 2.0 to 3.6 million tonnes across all modeled food items.

6.3 Available future food exports

Future food exports to the UAE from the major food exporting countries were projected on the basis of three key assumptions. First, it was assumed that overall agricultural productivity for each of the 29 food items for each of the major exporting countries was defined by the

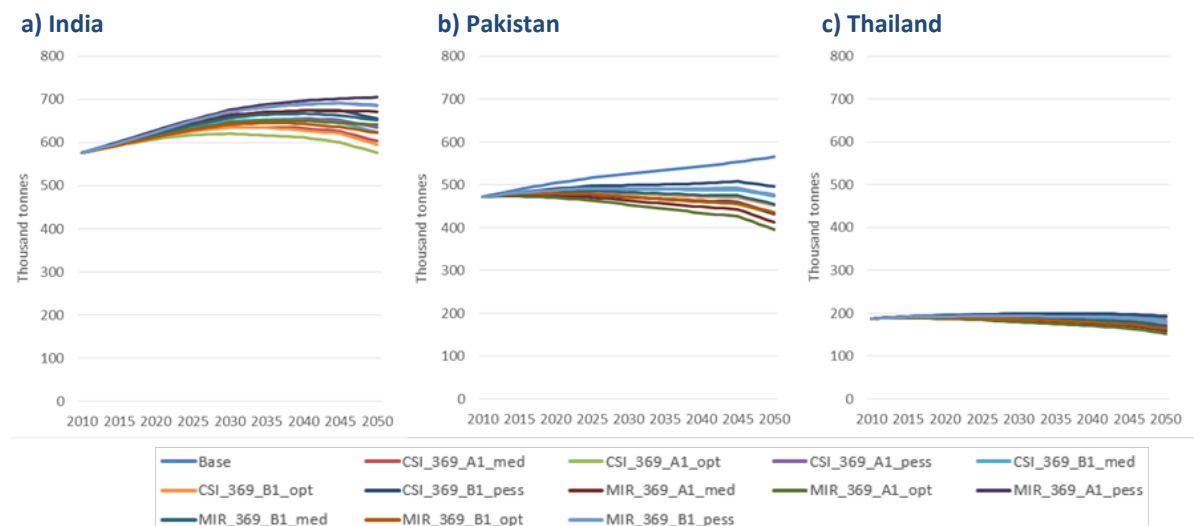
supply outputs from the IMPACT model. These outputs corresponded to the Baseline Scenario and each of the 12 Climate Impact scenarios (see earlier discussion in Section 5.2). They were provided for the 2000-2050 period and were normalized for the 2010-2050 period used in the analysis. This assumption is focused on establishing the growth or decline in annual agricultural productivity under each scenario. Second, it was assumed that the magnitude of food exports available to the UAE from any exporter would be proportional to the rates of change in agricultural production in that country. This assumption is primarily focused on establishing an upper limit of available exports to the UAE under the various scenarios at the individual country level. Third, it was assumed that the total annual supply of a given food item is the sum of the three major exporters plus an aggregate estimate for the rest of the world. This assumption is primarily focused on establishing an upper limit of available exports to the UAE under the various scenarios at the global level.

On the basis of the above assumptions, available annual exports for each of the 29 modeled food items were projected for each of the top exporting countries in the UAE's food supply profile for all 13 scenarios. The formula used for project annual available food exports to the UAE is provided below:

$$E_{i,j,c,t} = (EB_{i,j} * G_{i,c,t})$$

Where:

Figure 7-2: Projected available rice exports to the UAE for top historical exporters, 2010-2050; all Climate Impact scenarios



$E_{i,j,c,t}$ = Available exports (000 tonnes) to the UAE of food item i, by exporting country j, under Climate Impact Scenario c, in year t

$EB_{i,j}$ = Exports in the Base Year (2010) to the UAE (000 tonnes) of food item i, from exporting country j

$G_{k,t}$ = Annual rate of change in the agricultural productivity of food item I, under Climate

Impact

Scenario c, in year t

Detailed available export projections were developed for each major food-country combination. The result was a series of projections that quantified the magnitude of available exports by food item, by category of food exporter, by climate scenario. Figure 7-2 shows an illustrative set of the results for available rice exports to the UAE by its major traditional exporters, namely India, Pakistan, and Thailand. Overall, available rice exports to the UAE are projected to show declining trends for each major exporter depending on the climate change scenario. This is particularly evident for the current primary rice exporter, India, which under the most adverse climate scenario experiences in decline in available exports such that available exports in 2050 are essentially the same as available exports in 2010.

6.4 Food supply and demand

The comparison of UAE food import requirements and available food exports from major exporters was premised on one key assumption. That is, it was assumed that differences between annual available exports to the UAE and annual import requirements by the UAE could be directly compared by the development of a cumulative shortfall/surplus metric. Two outcomes are possible. On the one hand, cumulative available exports that are in excess of cumulative UAE import requirements for a particular food item would indicate a surplus whereby future exports could continue at historical rates. On the other hand, cumulative available exports that are less than cumulative UAE import requirements for a particular food item would indicate a deficit whereby future exports would be constrained due to climate change and other factors influencing agricultural productivity in exporting countries. On the basis of the above assumptions, cumulative shortfall/surplus metrics were developed for each of the 29 modeled food items for each of the top exporting countries in the UAE's food supply profile for all 13 scenarios. The formula used for project annual available food exports to the UAE is provided below:

$$S_{i,j,c} = \sum_{t=2010}^{2050} (E_{i,j,c} - I_{i,j})$$

Where:

$S_{i,j,c}$ = Cumulative Shortfall/Surplus of available exports (000 tonnes) to the UAE of food item i, from exporting country j, under Climate Impact Scenario c

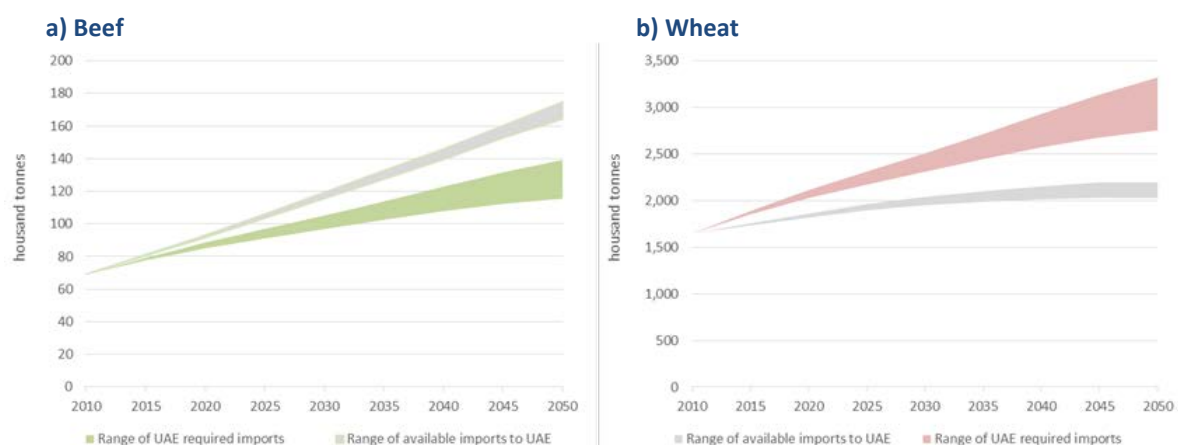
$E_{i,j,c}$ = Cumulative available exports to the UAE (000 tonnes) of food item i, from exporting country j, under Climate Impact Scenario c

$I_{i,j,c}$ = Cumulative required imports of food item I from exporting country j

Detailed annual and cumulative shortfall/surplus metrics were developed for each major food-country combination. The result was a series of projections that characterized whether a historical food trading partner would be constrained or unconstrained relative to future exports to the UAE. Figure 7-3 shows an illustrative set of the results at the annual level for an unconstrained commodity (beef) and a constrained commodity (wheat). For the unconstrained case, as can be seen in the Figure, the range in required imports of beef across all population growth variants is less than available exports of beef across all major exporters and across all scenarios. For the constrained case, the range in required imports of wheat across all population growth variants is greater than available exports of beef across all major exporters and across all scenarios. The bullets below summarize the numerical conventions used in EFFSeCC to characterize cumulative shortfall/surplus metrics.

- *Negative values:* Cumulative import gaps (whether a surplus or shortfall) that are negative for all climate change scenarios indicate that the food-country combination is fully unconstrained. This means that climate change and other national agricultural production conditions do not adversely affect future bilateral food trade with the UAE.
- *Positive values:* Cumulative import gaps (whether a surplus or shortfall) that are positive for all climate change scenarios indicate that the food-country combination is constrained. This means that climate change and other national agricultural production conditions adversely affect future bilateral food trade with the UAE.
- *Positive and negative values:* Cumulative import gaps that contain either positive or negative values for the climate change scenarios indicate that the food-country combination is partially constrained. This means that climate change and other national agricultural production conditions adversely may affect future bilateral food trade with the UAE.

Figure 7-3: Annual range in Surplus (left) and Shortfall (right) metric for top historical exporters, 2010-2050; all Climate Impact scenarios



6.5 Inputs to the development of macro-level vulnerability indicators

Cumulative food import shortfalls/surpluses provide a way to capture temporal effects of climate change on projected available exports to the UAE. That is, when summed across all years and for each of the 12 climate change scenarios, a quantification of the cumulative gap between required imports and available exports was developed. This is simply a metric to denote a situation where cumulative food export supply are not consistent with UAE cumulative food import demand. As such it is directly related to the vulnerability of the UAE to future food import constraints due to climate change. The use of cumulative food import gaps results in a more robust metric than annual food gaps to capture temporal effects and is used as an input to quantify the macro-level vulnerability of the UAE is discussed in the last section.

7. Micro-level modeling

This section provides an overview of the macro-modeling approach used to produce the range of outputs needed for determining the food security of the UAE under climate change. As discussed earlier, the “micro level” refers to an assessment of the UAE’s future food security under climate as viewed through a household-level perspective. The section begins with a brief overview of the overall approach. This is followed by discussion of the framework for assessing household vulnerability to food price hikes, namely the categories of households considered. The final three sections address the assumptions used to characterize the most significant components of household vulnerability: food price inflation, household income and impacts of climate change of future food prices.

7.1 Introductory remarks

The information in this section underlies the modeling approach that was used to evaluate the degree to which households in the UAE are vulnerable to future food price increases due to climate change. Micro-level modeling aimed to integrate all of the socioeconomic data presented earlier into a scenario-driven, household-stratified analysis framework. A planning period of 2010 to 2050 was used. Three key parameters were the focus of micro-modeling, namely establishing plausible projections of baseline inflation regarding food and other items; establishing plausible projections of household disposable income levels, and developing a method to incorporate into the micro-modeling framework the results of IMPACT projections of food price increases for the 29 modeled food items. The sequence of calculations involved in the estimation and use of these parameters was codified in the EFFSeCC model to enable exploring sensitivities regarding key assumptions.

7.2 Vulnerable group categories

For the purpose of micro-modeling at the household level, the UAE population was characterized by ten groups (deciles) differentiated by average annual household disposable income. Each of these groups had the same number of households. That is, of the 1.7 million households in the UAE 2014, one tenth of them (i.e., 171,126 households) are included in Decile 1, one tenth in Decile 2, and so forth. Each of the households per decile is characterized by a certain annual household income range. For the purposes of the analysis, it was assumed that the same household size of a little over 5 persons per household would be stable over the 2010-2050 period. Specifically, the following ten decile groups were considered as the framework for micro-modeling:

- *Low income households:*
 - *Decile 1:* Households with average annual income levels less than 25% of the average annual household income.
 - *Decile 2:* Individuals with a gross income between 25% and 50% of the average annual household income
 - *Decile 3:* Individuals with a gross income between 59% and 75% of the average annual household income
- *Middle income households:*
 - *Decile 4:* Individuals with a gross income between 75% and 95% of the average annual household income
 - *Decile 5:* Individuals with a gross income between 95% and 115% of the average annual household income
 - *Decile 6:* Individuals with a gross income between 115% and 130% of the average annual household income
 - *Decile 7:* Individuals with a gross income between 130% and 150% of the average annual household income
- *High income households:*
 - *Decile 8:* Individuals with a gross income between 150% and 175% of the average annual household income
 - *Decile 9:* Individuals with a gross income between 175% and 200% of the average annual household income
 - *Decile 10:* Individuals with a gross income greater than 200% of the average annual household income

This type of classification system was selected in order to make most use of the available household-level data presented and discussed previously. One limitation in separating the UAE population into deciles is that, while it enables direct comparisons across income groups

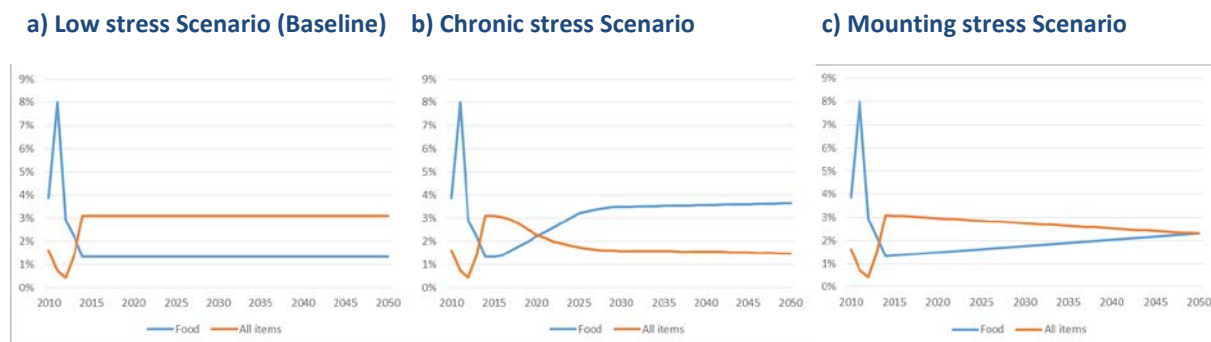
throughout the UAE, it does not lend itself to direct comparisons between households across the seven emirates.

7.3 Consumer price index projections

The rate at which food prices increase relative to overall inflation is a key factor in understanding vulnerability of specific groups in the UAE. Information on CPI forecasts for the UAE are limited. At present, official forecasts from the NSB for the CPI correspond to the period ending in 2017 and addresses overall inflation level only rather than individual categories that make up the CPI. International finance organizations like the World Bank and the International Monetary Fund (IMF) also do not provide long-term CPI forecasts.¹³ For example, World Bank projections extend to 2017. The IMF's most recent World Economic Outlook provides overall CPI projections extend to 2020 (IMF, 2015). For the UAE, the IMF projects annual overall inflation to be 2.3% by that year.

For these reasons, the UAE's CPI was projected using a scenario approach that built off historical trends and international financial organization assessments. Specifically, the following scenarios were considered to apply to all emirates regarding the food portion of the CPI and the total CPI. These projections of inflation levels bracket what are considered to be a plausible range in inflation trends in the UAE and minimum, maximum, and middle estimates of the relationship between food prices and overall prices. They were developed for the full period of the assessment (i.e., 2010-2050) for each of the scenarios, as illustrated in Figure 8-1. These scenarios are independent of any climate change impacts.

Figure 8-1: Annual inflation level scenarios for the UAE, 2010-2050



- *Low stress (Baseline).* In this scenario, both the food and total annual inflation continue at the same levels as experienced in 2014. For this year, the UAE annual food inflation level was about half the overall inflation level. This represents a future where the relationship between the average annual food price inflation relative to the average overall annual inflation rate is one of low stress on household food budgets.

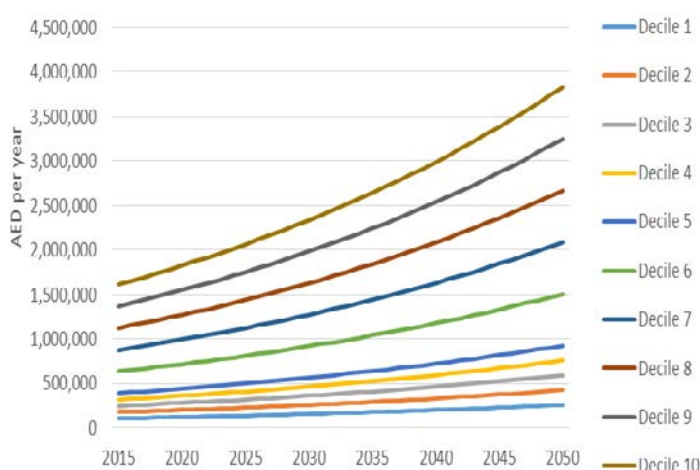
¹³ For example, the IMF's most recent World Economic Outlook provides overall CPI projections only to 2020 (IMF, 2015)

- *Chronic stress.* In this scenario, food annual inflation rapidly increases from the 2014 level over the period 2104-2025, then gradually increases to reach the average annual level over the 2008-2014 period by 2050. Overall inflation gradually decreases from the 2014 level to the average level over the 2008-2014 period by 2050. This represents a future where the relationship between average annual food price inflation relative to the average annual overall inflation rate is one of chronic stress on household food budgets.
- *Mounting stress.* In this scenario, both food and overall annual inflation gradually converge on the mid-term 2.3% level by 2050. This is the overall inflation rate forecasted in the WEO 2015 report for the UAE in 2020 (IMF, 2015). This represents a future where the relationship between average annual food price inflation relative to the average annual overall inflation rate is one of mounting stress on household food budgets.

7.4 Household income projections

The rate at which household incomes increase relative to overall inflation is another key factor in understanding vulnerability of specific groups in the UAE. Information on

Figure 8-2: Annual household income projections, 2010-2050



household income projections for the UAE are limited. At this time, only average household income projections are available for all households from EI (2015). As discussed previously, between 2015 and 2030, overall per household average annual disposable income is projected to rise by about 44%, or an average of 2.5% per year in real terms, to reach AED766,462 (US\$208,701) by 2030. This rate of increase is assumed to apply to all decile groups. Figure 8-2 summarizes household income

projection over 2015 to 2050 for each decile.

7.5 Consumer food price projections under climate change

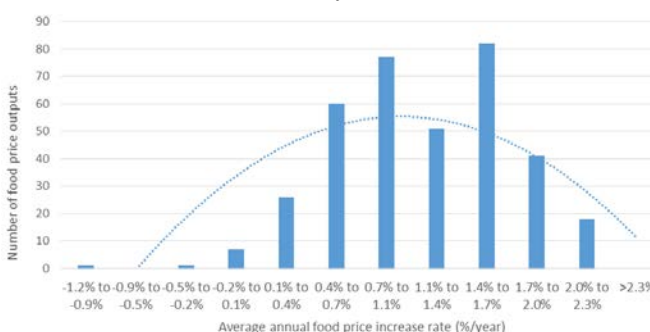
Consumer food prices were obtained from the outputs of the IMPACT model for the 29 modeled food items under the 13 scenarios. In IMPACT, consumer prices are provided for the Gulf States as a region, as opposed to the UAE as an individual country ion that region.¹⁴ To identify key price trends, the annual average change in food prices was calculated for each food item over the 2010-2050 period. This reduced the dimensionality of the dataset from

¹⁴ The Gulf States region includes Kuwait, Saudi Arabia, Bahrain, Qatar, UAE and Oman.

15,080 (i.e., 29 food items, times 13 scenarios, times 40 years) outputs to 364 (i.e., 29 food items, times 13 scenarios, times 1 period from 2010-2050) outputs. The results plotted on the histogram shown in Figure 8-3.

The data show that most of the average annual increases in the modeled food prices (i.e., about 75%) range between 0.4%/year and 1.7%/year. A polynomial trend line overlies the histogram indicating a roughly similar normal distribution in the concentration of food price increase rates. Prices are in “real” economic terms (i.e., net of inflation). On the basis of these results, the following scenarios were used to establish the range of real annual food price increases experienced by consumers in the UAE.

Figure 8-3: Histogram synthesizing the distribution of average annual food price increase rates for all climate change scenarios, 2010-2050



- *Low food price increases from climate change.* In this scenario, average annual real food price increases across all food items in the UAE were assumed to be 0.85%/year from 2020 through 2050.
- *High food price increases from climate change.* In this scenario, average annual real food price increases across all food items in the UAE were assumed to be 1.18%/year from 2020 through 2050.

7.6 Inputs to the development of micro-level vulnerability indicators

The assumptions described above were integrated into a simple spreadsheet analysis framework to examine the impact of rising food prices on the share that households will typically spend on food. That is, the outputs of micro-level modeling was a quantification of the change in food expenditure shares over time for each decile under climate change compared to a) the decile baseline levels for UAE households in 2014 and b) an assumed international standard for the share of food expenditures that adequately characterize food secure households. For the former, food expenditure shares over time were calculated for the period 2015-2050. For the latter, the average annual food expenditure share by households in the EU (i.e., 17%) was assumed to be indicative of food secure households. As such, the change in food expenditure shares it is directly related to the relative vulnerability of households to future food price increases. The approach used to develop micro-level vulnerability indicators by household decile is discussed in the section that follows.

8. Development of food security vulnerability indicators

This section provides an overview of the macro-modeling approach used to produce the range of outputs needed for determining the food security of the UAE under climate change. As discussed earlier, the “micro level” refers to an assessment of the UAE’s future food security under climate as viewed through a household-level perspective. The section begins with a brief overview of the overall approach. This is followed by discussion of the framework for assessing household vulnerability to food price hikes, namely the categories of households considered. The final three sections address the assumptions used to characterize the most significant components of household vulnerability: food price inflation, household income and impacts of climate change of future food prices.

8.1 Introductory remarks

The information in this section underlies the modeling approach that was used to evaluate the degree to which households in the UAE are vulnerable to future food price increases due to climate change. Micro-level modeling aimed to integrate all of the socioeconomic data presented earlier into a scenario-driven, household-stratified analysis framework. A planning period of 2010 to 2050 was used. Three key parameters were the focus of micro-modeling, namely establishing plausible projections of baseline inflation regarding food and other items; establishing plausible projections of household disposable income levels, and developing a method to incorporate into the micro-modeling framework the results of IMPACT projections of food price increases for the 29 modeled food items. The sequence of calculations involved in the estimation and use of these parameters was codified in the EFFSeCC model to enable exploring sensitivities regarding key assumptions.

8.2 Macro-level vulnerability assessment

A macro-level Food Insecurity Index has been calculated for each modeled food item imported into the UAE. The basis for constructing the food insecurity index, by food item as well as by country, is the cumulative food import gap (whether it be a shortfall or a surplus), as discussed previously in the macro-modeling section. The development of this food insecurity index (hereafter: “Macro Index”) is described in the sub-sections below.

8.2.1 Overview

The Index - by food item - ranges from 1 to 10. A value of 1 represents a strongly food-secure item and 10 representing strongly food-insecure item. The bullets below outline the basic conceptualization of the Index.

- *Macro Index = 1:* This corresponds to future imports to the UAE of a food item that are unconstrained in all years.
- $2 \leq \text{Macro Index} \leq 5$: This corresponds to future imports to the UAE of a food item that are partially constrained in one or more years and for which the magnitude of the sum of the maximum cumulative and minimum cumulative food import gap is negative (i.e., meaning when all scenarios and years are accounted for, the net impact of climate change and

other factors may be positive for the food item). For any given food item, the actual value of the index between 2 and 5 is determined on the basis of the magnitude of the sum of the maximum cumulative and minimum cumulative food import gap, relative to other partially constrained food imports in this category.

- $5 \leq \text{Macro Index} \leq 7$: This corresponds to future imports to the UAE of a food item that are partially constrained in one or more years and for which the magnitude of the sum of the maximum cumulative and minimum cumulative food import gap is positive (i.e., meaning when all scenarios and years are accounted for, the net impact of climate change and other factors may be negative for the food item). For any given food item, the actual value of the index between 5 and 7 is determined on the basis of the magnitude of the maximum cumulative food import gap, relative to other partially constrained food imports in this category.
- $6 \leq \text{Macro Index} \leq 10$: This corresponds to future imports to the UAE of a food item that are constrained in all years. For any given food item, the actual value of the index between 6 and 10 is determined on the basis of the magnitude of the difference between the maximum cumulative and minimum cumulative food import gap, relative to other food imports.

The Macro Index - by country – also ranges from 1 to 10. A value of 1 represents a strongly food export-secure country and 10 representing strongly food export-insecure country. The bullets below outline the basic conceptualization of the index.

- *Share of imports*: This corresponds to the weighted average share of exports to UAE relative to all other countries. This is the first of two criteria. Countries were classified from 1 to 10, with 1 indicating a very low share of imports and 10 indicating a very high share of UAE imports.
- *Impact of climate change relative to agricultural production in the Baseline Scenario*: This corresponds to the maximum change in production under the climate change scenarios relative to Baseline production. This is the second of two criteria. Countries were classified from 1 to 10, with 1 indicating a very low impact of climate change on national agricultural production and 10 indicating a very high impact of climate change on national agricultural production.
- *Food Insecurity Index, by country*: The two criteria were evenly weighted and a simple average was calculated to represent the Food Insecurity Index, by country. The effect of equal weighting and a simple average is ensure that the driving factors underlying risk of future food supply disruptions are accounted for. For example, countries that contribute a high share of exports to the UAE (i.e., high dependence) and have a high climate change impact (i.e., likely future food import disruptions possible) to result in a high Food Insecurity Index, by country.

8.2.2 Methodology

There were several variables and equations used to developed the Macro Index - by food item. These are briefly described below.

$$FIS = \begin{cases} \text{"Unconstrained"} , & \text{for } R_{min} - A_{max} < 0 \text{ and } A_{min} - R_{max} \geq 0 \\ \text{"Partially constrained"} , & \text{for } R_{min} - A_{max} < 0 \text{ and } A_{min} - R_{max} \leq 0 \\ \text{"Constrained"} , & \text{for } R_{min} - A_{max} \geq 0 \end{cases}$$

Where:

FIS is defined as the Food Import Status

R_{min} is the minimum required food import quantity to the UAE based on population projections

R_{max} is the maximum required food import quantity based on the maximum population growth scenario

A_{min} is the minimum actual food import quantity available to the UAE based on the climate change scenarios

A_{max} is the maximum actual food import quantity available to the UAE based on the climate change scenarios.

Different criteria were used to relate the Food Import Status (FIS) to the ordinal Food Security Index by Food Item, FSI_F from 1-10, depending on the FIS . For "Unconstrained" food items, the FSI_F is always 1. For "Constrained" food items, the FSI_F ranges from 6 thru 10. For "Partially Constrained" food items, the FSI_F ranges from 2 thru 5.

There were three steps involved in the calculation of the FSI for "Constrained" food items. First, the minimum food-specific import gap value is subtracted from the maximum food-specific import gap value:

$$GAP_{f,diff} = GAP_{f,max} - GAP_{f,min}$$

Where:

GAP_{max} is the maximum import gap across all climate scenarios for the high population growth scenario

GAP_{min} is the minimum import gap across all climate scenarios for the low population growth scenario, and

GAP_{diff} is the difference between those two terms.

Table 9-1: Relationship of Ω to the Macro Index by food (FSI_F)

Ω Range	FSI_F
$\Omega < 0.2$	6
$0.2 < \Omega \leq 0.4$	7
$0.4 < \Omega \leq 0.6$	8
$0.6 < \Omega \leq 0.8$	9
$0.8 < \Omega$	10

Second, food-specific GAP_{diff} is divided by the maximum GAP_{diff} across all food items. This variable provides an indication of the magnitude of the gap relative to its maximum. The equation is as follows:

$$\Omega = \frac{GAP_{f,diff}}{GAP_{max\ diff}}$$

Where:

$GAP_{f,diff}$ is the food-specific difference between import gaps value

$GAP_{max\ diff}$ is the maximum difference across all food items

Ω is the resulting fraction.

Third, the variable was broken out into distinct bins. Table 9-1 provides a summary of these bins that Ω to its resultant FSI_F .

For “Partially Constrained” food items, where FSI_f ranges from 2 thru 5, a complementary approach was used. First, the food-specific maximum import gap value, and food-specific minimum import gap value, across all climate scenarios is summed:

$$\Phi_f = GAP_{f,max} + GAP_{f,min}$$

Where:

GAP_{max} is the maximum import gap across all climate scenarios for the high population growth scenario

GAP_{min} is the minimum import gap across all climate scenarios for the low population growth scenario,

Φ is the sum of those two terms.

Then, the variable was broken out into distinct bins. Table 9-2 provides a summary of these bins linking Φ to its resultant FSI_f . If Φ_f is less than or equal to zero, then FSI_f falls into the range of 1 and 2, depending on import quantity available. If Φ_f is greater than zero, then FSI_f falls into the range of 3 and 4, depending on the magnitude of the gap.

Table 9-2: Relationship of Φ to the Macro Index by food (FSI_f)

Primary condition	Secondary Condition	FSI_f
$\Phi \leq 0$	$0 > A_{f,min} - R_{f,max}$	2
	$0 \leq A_{f,min} - R_{f,max}$	3
$\Phi > 0$	$0.66 < \frac{GAP_{f,diff}}{GAP_{max,diff}}$	4
	$0.66 \geq \frac{GAP_{f,diff}}{GAP_{max,diff}}$	5

8.2.3 Results

Table 9-3 provides a summary of the results of applying the methodology described above at both the food and country levels. Green-shaded rows indicate high food import security under climate change (Index =1 to 2). Light red-shaded rows indicate increasing levels of food import insecurity under climate change countries (Index = 5 to 10, where 10 indicates the highest level of food import insecurity). Light brown-shaded rows indicate the middle range of food import insecurity (Index =3 to 4).

For the food item portion of the Macro Index, Table 9-3a indicates that most food imports will be constrained under climate change. In particular, rice and wheat are strongly insecure food items for the UAE under climate change. Both of these cereals show a Food Insecurity Index of 10 which indicates that future food import gaps are large and adaptation strategies should be considered to reduce the potential constraints in import supplies. On the other hand, beef, lamb meat, and maize are strongly food secure items suggesting that current food trade flows will not be adversely affected in the future.

Table 9-3: Macro-level Food Insecurity Index results

a) By modeled food item

Food item	Food import status	Food Security index
BEEF (i.e., Bovine Meat)	UNCONSTRAINED	1
CASS (i.e., Cassava and	CONSTRAINED	6
CHKP (i.e., Pulses, and	PARTIALLY CONSTRAINED	3
EGGS (i.e., Eggs)	PARTIALLY CONSTRAINED	2
GRND (i.e., Groundnuts	CONSTRAINED	6
LAMB (i.e., Mutton & Goat	UNCONSTRAINED	1
MAIZ (i.e., Maize and	UNCONSTRAINED	1
MILK (i.e., Milk - Excluding	PARTIALLY CONSTRAINED	3
MILL (i.e., Millet and	CONSTRAINED	6
OGRN (i.e., Barley and	CONSTRAINED	6
PKOL (i.e., Oil - Palm and	PARTIALLY CONSTRAINED	3
PORK (i.e., Pigmeat)	CONSTRAINED	6
POTA (i.e., Potatoes and	PARTIALLY CONSTRAINED	5
POUL (i.e., Poultry Meat)	PARTIALLY CONSTRAINED	3
RICE (i.e., Rice (Milled	CONSTRAINED	10
RPOL (i.e., Rape and	CONSTRAINED	6
RPSD (i.e., Rape and	CONSTRAINED	6
SBOL (i.e., Soyabean Oil)	CONSTRAINED	6
SFOL (i.e., Sunflowerseed	CONSTRAINED	6
SNFL (i.e., Sunflower seed)	CONSTRAINED	6
SOYB (i.e., Soybeans)	CONSTRAINED	7
SUBF (i.e., Fruit -	CONSTRAINED	8
SUGC (i.e., Sugar (raw))	PARTIALLY CONSTRAINED	2
SUGR (i.e., Sugar (Refined))	CONSTRAINED	7
SWPY (i.e., Sweet potatoes)	CONSTRAINED	6
TEMF (i.e., Fruit -	CONSTRAINED	7
TOOL (i.e., Oil - Other)	CONSTRAINED	4
VEGE (i.e., Vegetables - All)	CONSTRAINED	8
WHEA (i.e., Wheat and	CONSTRAINED	10

b) By major exporting country

Country name	Criterion		Food Security index
	Share of Imports	Climate change impact	
Argentina	4	2	3
Australia	4	2	3
Brazil	7	3	5
Canada	2	1	2
China	2	3	3
Egypt	1	3	2
Ethiopia	1	2	2
France	1	3	2
Germany	2	5	4
Gulf countries	2	2	2
India	9	3	6
Indonesia	1	4	3
Iran (Islamic Republic of)	3	8	6
Jordan	2	2	2
Lebanon	1	2	2
Malaysia	2	4	3
Netherlands	2	2	2
New Zealand	1	2	2
Pakistan	3	4	4
Paraguay	2	3	3
Philippines	2	5	4
South Africa	2	10	6
Spain	1	2	2
Thailand	2	4	3
Ukraine	2	2	2
United States of America	2	4	3
All other countries	10	3	7

For the country portion of the Macro Index, Table 9-b indicates that there are several countries where food exports will be constrained. These countries include Brazil, India, Iran, and South Africa. Each of these countries has an Index of at least 5. On the other hand, tradition exports such as Pakistan, Germany, and Thailand are strongly food secure countries suggesting that current food trade flows from these countries will not be adversely affected in the future in comparison to the countries with higher index values.

8.3 Micro-level vulnerability assessment

A micro-level Food Insecurity Index has been calculated for each household decile for the range of scenarios. The basis for constructing the micro-level food insecurity index is the extent to which the share of household food expenditures exceeds a certain level considered to be a plausible characterization of a food secure situation at the household level (i.e., 17%), as discussed previously in the micro-modeling section. The development of this food insecurity index (hereafter: "Micro Index") is described in the sub-sections below.

8.3.1 Overview

The Micro Index ranges from 1 to 5. A value of 1 represents a strongly food-secure household and 5 representing strongly food-insecure household (i.e., least vulnerable to food price

shocks under climate change). The bullets below outline the basic conceptualization of the Index.

- *Micro Index = 1:* This corresponds to a situation where household food expenditure shares are less than or equal to 17%. These households are very highly food secure and are the least vulnerable to food price shocks under climate change.
- *Micro Index = 2:* This corresponds to a situation where household food expenditure shares are more than 17% and less than or equal to 24%. These households are highly food secure relative to food price shocks under climate change.
- *Micro Index = 3:* This corresponds to a situation where household food expenditure shares are more than 24% and less than or equal to 32%. These households are moderately food insecure relative to food price shocks under climate change.
- *Micro Index = 4:* This corresponds to a situation where household food expenditure shares are more than 32% and less than or equal to 40%. These households are highly food insecure relative to food price shocks under climate change.
- *Micro Index = 5:* This corresponds to a situation where household food expenditures are greater than 40%. These households are very highly food insecure and are the most vulnerable to food price shocks under climate change.

8.3.2 Methodology

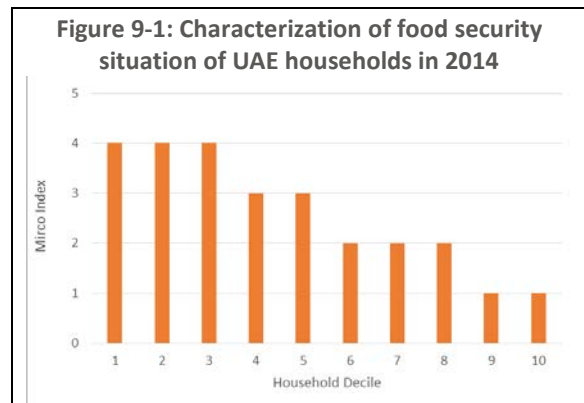
A 3-step process was used to develop the Micro Index. These are briefly described in the bullets below.

- *Integrate all assumptions.* This involved the integration of all assumptions (i.e., household incomes by decile, household food expenditure shares by decile, household income growth, food price inflation, real food price growth due to climate change) into an analytical framework for projecting household expenditure shares per decile over the period 2015-2050. Three scenario “families”¹⁵ were considered, namely no climate change, climate change under low consumer food price growth, and climate change under high consumer food price growth.
- *Determine number of vulnerable households.* This involved the calculation of the number of households within each of the 5 Micro Index categories. This enabled a comparison with the corresponding number of households in the Base Year of 2014.
- *Determine the change in household vulnerability.* This involved the calculation of the difference between future food insecurity and present day food insecurity. This offers a basis to characterize the future vulnerability of households to food price increases from climate change.

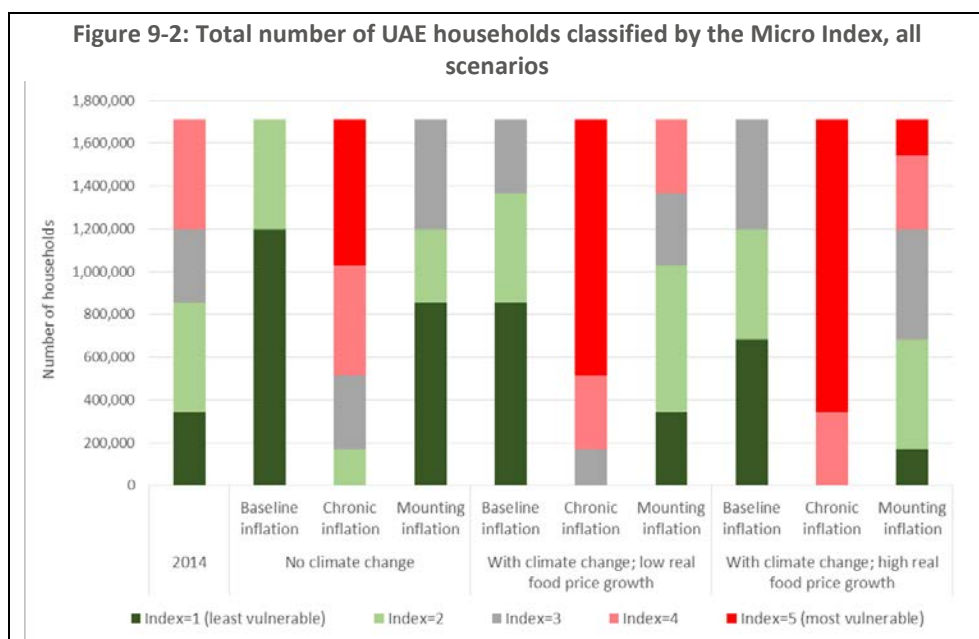
¹⁵ These were scenario families in the sense that there were three food price inflation trajectories considered within the each scenario family.

8.3.3 Results

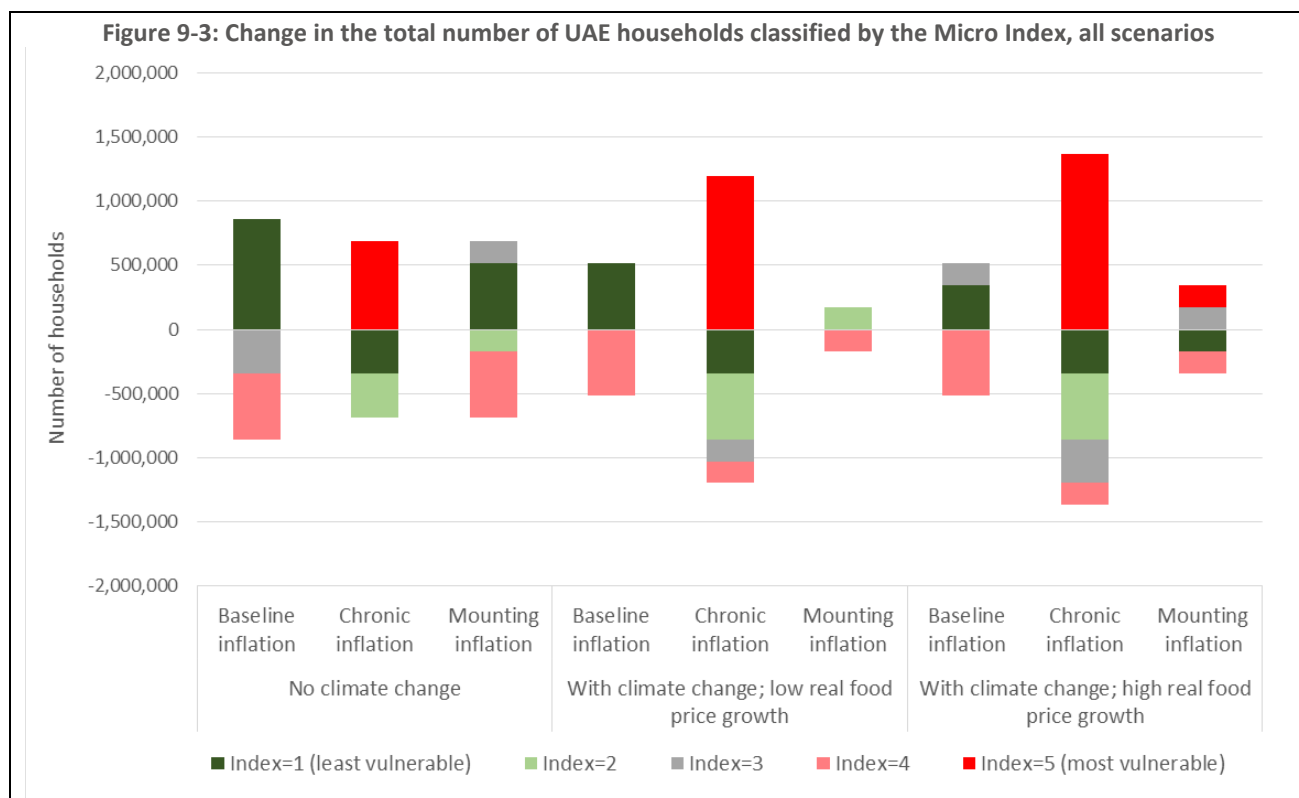
The starting point for a discussion of results is the level of household food security in the Base Year of 2014. This is illustrated in Figure 9-1 which shows that there are no households in the UAE that are currently considered very highly food insecure. Nevertheless, the households in the first three deciles (i.e., the least affluent households), about 503 thousand households, can be characterized as highly food insecure, meaning that current annual expenditures on food are between 32 and 40% of annual disposable income. At the other end of the spectrum, the households in the last two deciles (i.e., the most affluent households), are considered very highly food secure. Overall, about 856 thousand households across the UAE can be considered highly to very highly food secure at present.



An already precarious food security situation for low-income households in the UAE will worsen with climate change. This is illustrated in Figure 9-2 which shows that the number of households that are very highly vulnerable to food price increases (i.e., red bars) rise in the future relative to 2014. Notably, in the most optimistic scenario (i.e., where inflation continues at current levels and there are no climate change impacts), the food security situation for all the households in the UAE improve significantly. In this scenario construct, there are no households across the UAE that are food insecure (i.e., second column from left). In the most pessimistic scenario (i.e., where there is chronic inflation combined with high levels of food price increases under climate change), the food security situation for all the households in the UAE declines significantly. In this scenario construct, all households across the UAE that are highly to very highly food insecure (i.e., second column from right).



The impact of climate change on household food security is illustrated in Figure 9-3. This figure shows that climate change introduces serious shifts in food spending patterns. In particular, introducing climate change to an already highly stressed situation corresponding to the Chronic inflation scenario increases the number of the most vulnerable households from 685 thousand to 1.2 million (i.e., 75% increase) in the low real food price scenario and to 1.4 million (i.e., 100% increase) in the high real food price scenario. This reflects shift to greater spending on food as a percentage of annual household spending.



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