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The Impact of the 2008 Hadramout Flash Flood in Yemen on Economic Performance and Nutrition: A Simulation Analysis

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Abstract:

Combining a Dynamic Computable General Equilibrium (DCGE) model of the Yemeni economy with a microsimulation model that captures the link between changes in household incomes and changes in nutrition status, this paper provides a quantitative assessment of the agricultural, economy-wide, and nutritional impacts of the 2008 Hadramout flash flood in Yemen. The model simulations point to strong and persistent negative effects on agricultural value added, farm household incomes and nutrition among farmers in the region most severely affected by the flood. Regional spillover effects lead to temporary increases in hunger and significant cumulative income losses even in other regions where the flood has no direct impact.

Keywords: floods, agriculture, nutrition, CGE modeling, Yemen

JEL classification: I3, Q1, O5, C3

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1. Introduction

Extreme weather events such as floods and droughts have potentially devastating implications. The problem is likely to become even more severe in the future given that global climate change is expected to increase the severity and frequency of floods and droughts (Salinger 2005; WMO 2011). Developing countries with large agricultural sectors and limited capabilities to respond to the challenges of disasters are particularly vulnerable (e.g. Blankespoor et al. 2010). Designing appropriate adaptation and mitigation strategies for these countries requires a careful assessment of the impacts of extreme weather events. However, conducting such impact assessments is often complicated by the complex nature of the impacts and the limited availability of data. Isolating flood or drought effects can be challenging and if data is incomplete it may not always be possible to assess both the direct and indirect effects, which is why computable general equilibrium (CGE) models have recently been suggested as a suitable tool for disaster impact assessments (e.g. Pauw et al. 2011).

Along these lines, the present paper provides a model-based assessment of extreme weather events for one particular country, Yemen, focusing on the impacts of floods on agriculture and household-level food security while taking economy-wide effects into consideration. Yemen is an interesting case in point because it is a disaster prone country that faces a number of natural hazards every year with floods constituting the most important and recurring form of disaster in the country.[1] While regular flooding has traditionally been beneficial for agricultural practices in Yemen, high magnitude flooding often leads to losses of crop land, uprooting of fruit trees, animals dying because they are caught in high flood water surges, and destruction of infrastructure such as irrigation facilities and rural roads. The damages done by floods tend to be

[1] The Top 4 natural disasters in Yemen for the period 1990-2011 with regard to economic damages were all floods; see http://www.emdat.be/database.

exacerbated by an ongoing desertification process and land degradation. In addition, several Global Climate Models predict higher rainfall levels for Yemen, thus potentially increasing the frequency and severity of floods in the future.

Our quantitative impact assessment focuses on the October 2008 tropical storm and flood 03B, for which a joint assessment of the Government of Yemen, The World Bank, the UN International Strategy for Disaster Reduction, and the International Federation of the Red Crescent and Cross serves as the basis (GoY et al. 2009). The joint assessment concludes that the floods have been especially damaging for farmers and herders in the Wadi Hadramout and to a lesser extent in the Sahel Hadramout and the Al-Mahara governorate, but that the impact of the disaster reached beyond the affected regions, the agricultural sector and the rural population, hurting nonfarm households mainly through higher prices and thus reductions in real incomes. While the immediate local damages are well documented, the potential size of flood impacts in terms of overall and agricultural GDP losses and increases in hunger are less well understood. Our analysis sheds light on these broader effects by combining a CGE model of the Yemeni economy with a microsimulation model that captures the link between changes in household incomes and changes in food security levels.

The remainder of the paper is structured as follows. In section 2, we provide a short description of past floods in Yemen. Section 3 introduces the modeling framework and explains how it captures the damages caused by the 2008 flood. Section 4 presents the simulation results. The paper closes with some concluding remarks.

2. Significance of Floods in Yemen

According to the Emergency Events database (EM-DAT) approximately 100,000 people are affected annually by disasters triggered by natural hazards in Yemen. Over the past two decades, Yemen has become increasingly vulnerable to natural disasters, mainly due to high population growth, largely uncontrolled urbanization and lack of environmental controls. In addition, the concentration of physical assets and vulnerable population in high-risk areas has led to an increased exposure to adverse natural events.

Floods are the most important and recurring disaster in Yemen. Over the last two decades and since the unification of the Arab Republic of Yemen and People's Democratic Republic of Yemen in May 1990, Yemen had to endure 19 floods or flash floods. The International Disaster Database of the Center for Research on Epidemiology of Disasters (CRED, website: http://www.emdat.be/) ranked floods as the top four natural disasters in Yemen since 1990 with regard to the size of the economic damages caused. Floods also rank prominently with regard to killed persons (eight of the top ten are floods) and affected people (nine of the top ten are floods).

Table 1: Human toll and damages due to floods and flash floods, 1993-2008

Year	Month	Type	Duration (days)	Location	Killed	Affected	Damage (million US$)
1993	February	Flood	5	Lahej, Abyan, Aden	31	21,500	1.5
1996	May	Flood	4	Taiz, Hodeida	7	5,000	10
	June	Flood	12	Shabwa, Mareb, Hadramout	338	238,210	1,200
1998	August	Flash flood	16	Shihab Valley, Red Sea Port	70	240	NA
	March	Flood	3	Tihama Valley, Hodeidah		3,000	NA
1999		Flood		Socotra archipelago		19,750	NA
2002	August	Flood	1	Hodeidah, Taiz, Hadramout	28		NA
	July	Flood	2	Raima	13	700	NA
	July	Flood	2	Salafiyah	10		NA
	April	Flood		Salafiyah, Hadramout	2		NA
2003	June	Flood	3	Haija, Taiz	15		NA
2005	August	Flash flood	1		12	721	NA
	April	Flash flood	3	Sanaa, Hodeidah	10		NA
2006	April	Flash flood	2	Dhamar, Hodeidah, Manakha	25	320	NA
	February	Flash flood	3	Dhamar, Maabar	5	2,000	NA
2007	August	Flood			50		NA
	March	Flash flood	3	Hadramout, Ibb	36	618	NA
	January	Flood	3	Raima, Dhamar	7	2,000	NA
2008	October	Flash flood	2	Hadramout, Al-Mahara	75	25,000	1,235

Source: GoY et al. (2009).

The October 2008 tropical storm on which we focus here caused severe rain and flooding over the eastern parts of Yemen for about 30 hours, resulting in total rainfall of almost 91 mm (vs. 5-6 mm during normal periods). The total catchment area of about 2 million hectares collected some 2 billion cubic meters of water. Given the topography of the affected area (mountainous terrain, rivers and flat valleys), this large quantity of water in the catchment area led to severe flash floods in the valleys, with water surges reaching up to 18 meters in some areas. Moreover, the storm damaged boats and fishing equipment along the coastal line of the Arabian Sea. Overall, storm 03B resulted in one of the largest natural disasters to hit Yemen since the last decade (GoY et al. 2009). The heavy rain and flooding seriously affected Hadramout and Al-Mahara governorates, which were declared disaster areas on October 27, 2008. The Wadi Hadramout region fared worst as a result of the disaster, incurring 67.5 percent of the total damage and losses. Hadramout's coastal areas sustained another 28.6 percent of total damage and losses, while Al-Mahara accounted for the remaining 3.9 percent (GoY et al. 2009).

3. Modeling Framework

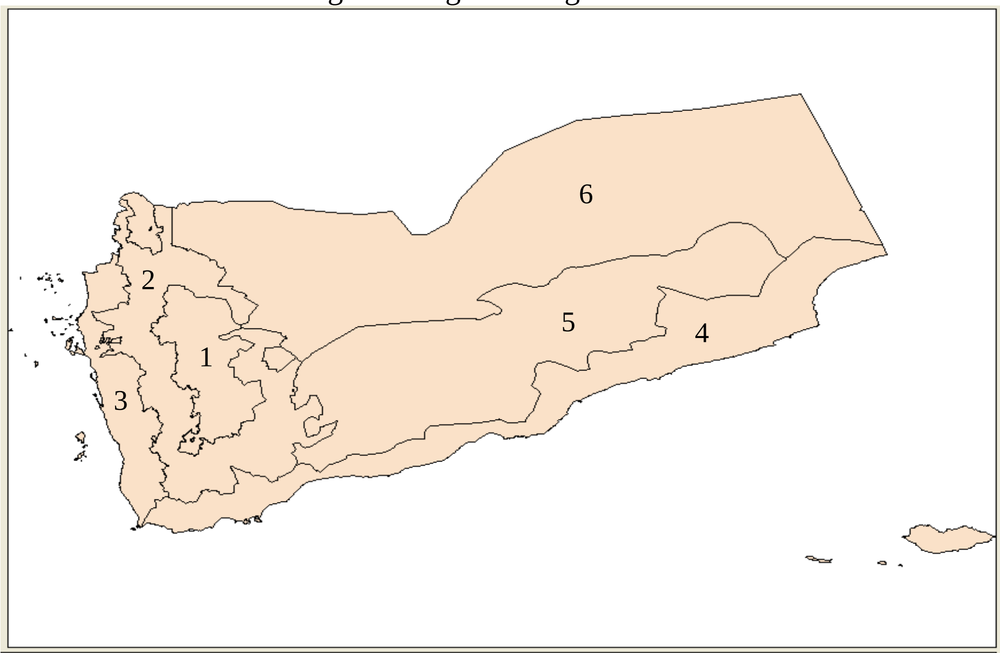
To quantify the agricultural, economy-wide, and nutritional impacts of the 2008 flood, we combine a CGE model with a microsimulation model in a sequential manner. Specifically, simulated income changes for the household groups identified in the CGE model enter the microsimulation model as a determinant of changes in individual households' nutrition status.

3.1. Economic Model

Within the limited CGE literature on extreme weather events, some analyses are ex-ante – assessing the impacts of hypothetical events (e.g. Boyd and Ibarraran 2009), and some are ex-post – evaluating the impacts of historical events (for example Horridge, Madden, and Wittwer 2005). We adopt an ex-ante approach, using historical data from the 2008 Hadramout flood and simulating its economy-wide impacts over a period of five years. An early version of this dynamic CGE (DCGE) model can be found in Thurlow (2004), while recent applications to Yemen include Breisinger et al. (2011a, 2011b).

The DCGE model for Yemen distinguishes six agro-ecological zones (Figure 1), which partly overlap with the regions affected by the Hadramout flood, thereby allowing us to capture the major linkages between the flooding, production and households. Wadi Hadramout is part of the Internal Plateau, i.e. agro-ecological zone 5 in Figure 1; the Sahel Hadramout governorate is included in agro-ecological zone 4, and the Al-Mahara governorate is divided between zones 4 and 5.

Figure 1: Agro-ecological zones in Yemen



1: Upper Highlands | Zone 2: Lower Highlands

Zone 3: Red Sea and Tihama Plain | Zone 4: Arabian Sea Coast

Zone 5: Internal Plateau | Zone 6: Desert

Producers in the model are price takers in output and input markets and maximize profits using constant returns to scale technologies. Primary factor demands are derived from constant elasticity of substitution (CES) value added functions, while intermediate input demand by commodity group is determined by a Leontief fixed-coefficient technology. The decision of producers between production for domestic and foreign markets is governed by constant elasticity of transformation (CET) functions that distinguish between exported and domestic goods in each traded commodity group in order to capture any quality-related differences between the two products. Under the small-country assumption, Yemen faces perfectly elastic world demand curves for its exports at fixed world prices. On the demand side, imported and domestic goods are treated as imperfect substitutes in both final and intermediate demand under a CES Armington specification. Households use their incomes to consume commodities according to a linear expenditure system (LES) specification as derived from a Stone-Geary utility function.

There are six labor categories in the model, differentiated by their skills (unskilled, semi-skilled, and skilled) and their dominating employment in public or private sectors. All types of labor are assumed to be fully employed and mobile across sectors. The assumption of full employment is consistent with widespread evidence that, while relatively few people have formal sector jobs, the large majority of working-age people engage in activities that contribute to GDP. Capital is also assumed to be fully employed and mobile across sectors reflecting the medium-term (1-5 years) perspective of this study. In agriculture cultivated land is fixed and cannot be reallocated across crops in response to shocks. This assumption reflects the scarcity and overuse of water in Yemen, which severely constrains the growth potential of the agricultural sector. Moreover, cropping decisions are made at the beginning of the period before the realization of the flooding shocks is imposed.

The DCGE model is specifically built to capture the economic, distributional, and nutrition effects of flooding in Yemen. Given the importance of agriculture for income generation and the satisfaction of consumption needs, the model captures both the sectoral and spatial heterogeneity of crop production and its linkages to other sectors such as food processing, manufacturing and services. The model includes 26 production activities and commodities, 9 factors of production and 18 household types. The 21 agricultural production activities are split into livestock (4), fishing (1), forestry (1) and crop production activities (15), where all agricultural production activities are specific to each agro-ecological zone. Other production sectors and commodities included in the model are mining, including oil (1), food processing (1), (other) manufacturing (1), electricity and water (1), and services. The household groups are first separated regionally by agro-ecological zones and, within each agro-ecological zone, into urban and rural households. We then split rural households in each agro-ecological zone into farm and nonfarm households. This differentiation of household groups allows us to capture the distinctive patterns of income generation and consumption and the distributional impacts of flooding.

Our model captures the damages caused by the Hadramout flash flood through reductions in land and livestock endowments. Table 2 shows the changes in cropped area (as a result of soil erosion) and livestock numbers (goats and sheep, cattle, camels; as a result of animals that were caught in the high flood water surge and died). These numbers serve as the base for implementing the flood shock in the DCGE model with the assumption that changes in crop land and livestock are entirely caused by the flood event. Moreover, we differentiate between immediate damages and longer-run losses of stocks. The damage estimates are based on quantities of the damaged assets such as planted and unplanted area for seasonal crops and livestock numbers. Losses refer to potential production losses from perennials and livestock spread over four years, reflecting that it takes time until replanted trees start bearing fruits and young animals produce meat and milk.

Table 2: Changes in crop land, number of animals, and fishery yields during and after Hadramout flashflood by agro-ecological zone (percent change of base year stocks)

	Base year stocks	Damages	Losses			
	2007	2009	2010	2011	2012	2013
	Yemen		The Internal Plateau (zone 5)			
Cropped area/acre	1,480,000	-81.6	7.7	56.1	24.0	22.6
Sheep&goats/head	17,003,000	-3.4	-1.6	-1.0	6.2	0.0
Cattle/heads	1,495,000	-1.4	1.0	-0.2	0.2	0.4
Camel/heads	366,000	-6.3	4.8	-0.6	0.6	0.0
			The Arabian Sea Coast (zone 4)			
Cropped area/acre		-39.3	3.7	27.0	11.5	10.9
Sheeps&goats/head		-0.8	0.6	-0.8	1.0	0.0
Cattle/heads		-1.6	1.3	-1.6	2.1	0.0
Camel/heads		-3.2	2.8	-3.4	4.4	0.0
Fish/real value added		-6.7	5.7	-7.0	9.1	0.0

Authors' calculations based on GoY et al. (2009).

3.2. Nutrition model

For assessing changes in people's hunger situation as a response to changes in their income levels (measured on the basis of household total expenditure), we use an expenditure elasticity-based approach that captures the percentage change in per capita calorie consumption to a one percent change in household total expenditure (used as proxy for household real income). The calorie consumption elasticities with respect to household expenditure are derived from a reduced-form demand model. The model has households' per capita calorie consumption as dependent variable and total per capita expenditure (in logarithmic terms) as independent variable and controls for structural differences between households in their gender and age composition and educational level, their levels of food self-sufficiency and qat consumption, and regional and seasonality patterns.[2] Depending on the income level, we calculate household-specific calorie consumption elasticities. On average, a one-percent increase in household per

[2] See Appendix 1 for the regression results.

capita income is associated with an increase in people's per capita calorie consumption of 0.3 percent.

To simulate the hunger effects of floods, we combine the annual real income growth rates obtained from the DCGE model with the calorie consumption elasticities from the econometric models for each household individually. Assuming specific changes in different macroeconomic parameters under the flooding scenario, we predict a new calorie consumption level for each household per annum, subject to the estimated annual income changes. The simulation equation is:

$$\hat{y}_{i,j} = y_{i,j-1} \cdot (1 + E_i \cdot c_{i,j}),$$

where $\hat{y}_{i,j}$ is a household's *i* predicted calorie consumption level under the flood scenario in year *j*, $y_{i,j-1}$ is the calorie consumption level in the previous year, E_i is the household-specific calorie consumption-expenditure elasticity, and $c_{i,j}$ is the annual income change of the household *i* the person belongs to in year *j*. A household's new calorie consumption level is then related to its individual requirement level to identify whether the household is suffering from hunger or is sufficiently supplied with dietary energy. The household-specific requirement levels are calculated based on the household's sex and age composition and the individual physiological dietary energy requirements of the household members, using standard reference levels from FAO/WHO/UNU (2001). Thus, households with calorie consumption levels below the household-specific threshold are considered as calorie deficient or hungry. Using household size and population estimates from the 2010 Revision of World Population Prospects (UN, 2010), we calculate the prevalence rate and number of hungry people.

4. Simulation Results

Before turning to the simulations, we briefly describe some structural characteristics of Yemen's economy and its food security situation in order to set the stage for the evaluation of climate change impacts.

4.1. Structure of the Yemeni economy and food security

Oil and agriculture are the two mainstays of the Yemeni economy, but oil production is on a declining trend. In the absence of new oil discoveries, it is estimated that Yemen may become a net importer of oil as soon as 2016. This will have a significant impact on the economy given that oil revenues account for 60 percent of government receipts and almost 90 percent of exports (IMF 2009 and Table 3). Yemen is also a net importer of major food items, including maize, wheat, other grains, livestock, fish and processed food. Agriculture's trade orientation is uneven, with imports accounting for more than a third of total domestic consumption and exports accounting for less than five percent of domestic production.

Agriculture and related processing contribute about 13 percent to GDP, about three quarters of which is produced in the highly populated agro-ecological zones 1 and 2 (the Upper and Lower Highlands, with 30 and 40 percent of the total population living in these zones). Qat – a mild narcotic – accounts for over one-third of agricultural GDP and about 40 percent of total water resource use. Vegetables and fruits make up another one-third of agricultural GDP. Livestock and cereals contribute about 20 and 10 percent to agricultural GDP, respectively (Table 4). Qat is almost exclusively concentrated in agro-ecological zones 1 and 2, while other water-intensive crops such as fruits and vegetables are also grown in zone 3 (the Red Sea and Tihama Plain). Agro-ecological zones 1 and 2 are the two main contributors to agricultural and overall GDP, followed by zones 3, 5, 4 and 6. The flood-affected zones 5 and 4 together account for only 7.3 percent of agricultural GDP, yet 20 percent of Yemen's fruits are produced in zone 5 and one third of total fish catch stems from zone 4. Food and agriculture-related processing makes up about 50 percent of household consumption expenditures. Within this category, food processing constitutes the largest share of consumption, followed by cereals, qat, vegetables and fruits (Table 3).

Table 3: Structure of the Yemeni Economy by Sector, 2009

	GDP	Private consumption	Export share	Export intensity	Import share	Import intensity
Sorghum	0.3	0.6	0.0	1.4	0.0	0.4
Maize	0.1	0.8	0.0	1.3	1.1	68.9
Millet	0.1	0.2				
Wheat	0.2	5.4	0.1	6.2	8.7	93.6
Barley	0.1	0.2				
Other grains	0.0	2.4			3.8	99.8
Fruits	0.9	1.5	0.5	12.0	0.3	10.0
Potatos	0.4	0.7	0.2	9.3	0.0	1.1
Vegetables	1.1	2.3	0.1	2.0	0.1	3.2
Pulses	0.2	0.4				
Coffee	0.2		0.5	54.7	0.0	2.6
Sesame	0.0		0.0	10.4		
Cotton	0.1		0.0	5.3	0.0	3.3
Qat	2.8	5.5				
Tobacco	0.2	0.8			0.8	61.1
Camel	0.1		0.5	71.0	0.0	15.5
Cattle	0.4		0.1	2.3	0.2	10.0
Poultry	0.6				0.5	10.5
Goat&sheep	0.4		0.1	3.1	0.3	15.7
Fish	0.3		0.0	0.1	0.0	0.3
Forestry	0.2	0.7			0.5	41.9
Mining	22.5	1.0	88.7	95.0		
Food processing	4.0	26.5	1.5	3.6	13.9	33.8
Other industry	10.9	18.8	1.2	1.9	69.7	61.3
Utilities	1.2	1.9				
Services	53.1	30.4	6.6	2.2		
TOTAL, of which:	100.0	100.0	100.0	18.0	100.0	24.0
Agriculture	8.4	21.5	2.1	4.5	16.3	34.4
Non-agriculture	91.6	78.5	97.9	19.2	83.7	22.7

Source: Yemen DCGE model

Table 4: Agricultural value added by zone and crop, 2009 (Billions of Yemeni Rials and percent)

Activity	zone 1		zone 2		zone 3		zone 4		zone 5		zone 6		Total	
	billions YR	per-cent	billions YR	per-cent	billions YR	per-cent	billions YR	per-cent	billions YR	per-cent	billions YR	per-cent	billions YR	per-cent
Sorghum	7.36	5.25	5.10	3.09	3.65	4.71	0.07	0.67	0.10	0.54	0.00	0.01	16.29	2.68
Maize	2.50	1.78	4.09	2.48	0.35	0.46	0.01	0.06	0.01	0.04	0.00	0.02	6.96	1.12
Millet	1.83	1.31	0.55	0.33	2.59	3.35	0.03	0.29	0.01	0.03	0.00	0.00	5.01	0.96
Wheat	1.03	0.73	6.05	3.66	0.17	0.22	0.00	0.00	0.19	0.97	0.05	1.95	7.48	1.23
Oth. grains	0.19	0.14	3.53	2.14	0.04	0.05			0.01	0.05	0.00	0.03	3.76	0.91
Fruits	4.55	3.25	8.35	5.06	23.87	30.80	0.15	1.35	8.81	45.81	0.02	0.84	45.76	13.86
Potatos	15.78	11.26	0.79	0.48	0.86	1.10	0.01	0.05	0.18	0.94	0.00	0.02	17.60	2.62
Vegetables	8.88	6.34	11.67	7.07	7.36	9.49	2.29	20.65	1.33	6.91	0.04	1.34	31.56	8.25
Tomatos	10.78	7.69	3.62	2.19	5.22	6.74	0.20	1.77	2.04	10.62	0.03	1.26	21.90	4.68
Pulses	5.77	4.12	0.70	0.43	1.51	1.95	0.19	1.70	0.05	0.25	0.01	0.34	8.23	1.26
Coffee	0.29	0.21	7.41	4.49	0.02	0.03							7.73	1.21
Sesame	0.03	0.02	0.04	0.02	0.34	0.44	0.00	0.03	0.59	3.07	0.27	10.45	1.27	0.48
Cotton			0.24	0.15	5.02	6.48	0.05	0.41	0.00	0.00		0.00	5.31	5.17
Qat	55.95	39.93	84.18	50.99	0.06	0.08	0.00	0.01	0.00	0.00	0.02	0.57	140.20	18.93
Tobacco			0.11	0.06	8.54	11.01	0.01	0.07					8.65	1.97
Camel	0.22	0.16	0.52	0.31	0.28	0.36	0.52	4.71	1.20	6.23	1.34	51.09	4.07	1.82
Cattle	3.75	2.68	10.25	6.21	3.66	4.72	0.51	4.61	0.12	0.64	0.06	2.45	18.36	4.65
Poultry	17.38	12.40	10.18	6.16	1.42	1.83	0.41	3.65	0.59	3.05	0.03	1.19	29.99	4.69
Goat, sheep	3.83	2.74	7.73	4.68	2.45	3.17	2.58	23.26	4.01	20.86	0.74	28.43	21.36	7.26
Fish					10.09	13.02	4.08	36.71					14.17	16.22
Total	140.11	100.00	165.09	100.00	77.50	100.00	11.10	100.00	19.23	100.00	2.61	100.00	415.66	100.00
Percent	33.71		39.72		18.64		2.67		4.63		0.63		100.00	

Source: Yemen DCGE model

The food security situation in Yemen is highly vulnerable to shocks such as climate variability and flooding. The vulnerability is demonstrated by the relatively small difference between what Yemenis consume every day and what they need to stave off hunger at their current level of activity—less than 300 kcal/day nationwide (Table 5). This means that the average Yemeni consumes only 15 percent more than the 2,019 kcal/day needed to avoid hunger.

Table 5: Food insecurity by residential area and agro-ecological zones in 2009

	Food Insecurity Rate (percent)	Number of Food Insecure People (thousand)	Per Capita Calorie Consumption (kcal/day)	Per Capita Calorie Gap (kcal/day)	Food Variety Score (foods/week)
All	**32,1**	**7 481**	**2 301**	**282**	**17,3**
Urban	17,7	1 102	2 160	380	**21,0**
Rural	37,3	6 378	2 352	246	**16,0**
Agroecological Zones					
Highlands ≤ 1,900 m	19,4	1 197	2 411	443	18,9
Highlands > 1,900 m	36,5	3 739	2 323	252	16,5
Red Sea & Tihama	27,7	920	2 362	360	17,7
Arabian Sea	35,3	568	2 027	142	17,6
Internal Plateau	56,5	868	1 909	-142	16,6
Desert	44,0	189	2 167	119	13,7

Source: IFPRI estimation based on 2005–2006 HBS data.

People in rural areas are more likely to fall into food insecurity than people living in urban areas. Although the average per capita calorie consumption is higher by 200 kcal/day in rural areas than in urban areas, the average per capita calorie gap is lower by about 130 kcal/day. This difference is the result of the significantly higher calorie needs of rural people (2,106 kcal/day on average) compared with urban people (1,708 kcal/day on average). Rural people need more calories for fetching water from wells, carrying goods to and purchases from markets over long distances, and working hard on farms and in fisheries.

At the regional level the food insecurity rate strongly varies between agro-ecological zones (Table 5). The prevalence rate is lower along the Red Sea Coast (Red Sea and Tihama zone) and in the Upper Highlands zone (which starts at 1,900 meters above sea level), where the country's capital, Sana'a, is located. The food-insecurity rate rises toward the eastern inland region, which is comprised of the Internal Plateau and the Desert zone. The food-insecurity rate is lowest in the Lower Highlands (located at an altitude of 1,500 to 1,900 meters above sea level), home to less than 20 percent of the population. It is alarmingly high in the Internal Plateau, where more than half the population is food insecure and where the Hadramout flood hit hardest. The agro-ecological zones that are better off in terms of food security also have high percentages of urbanized population. The Internal Plateau is the only zone showing an average calorie deficit exceeding 140 kcal/day. Thus the availability of dietary energy (at affordable prices) in this zone is insufficient to supply all people there with adequate calories.

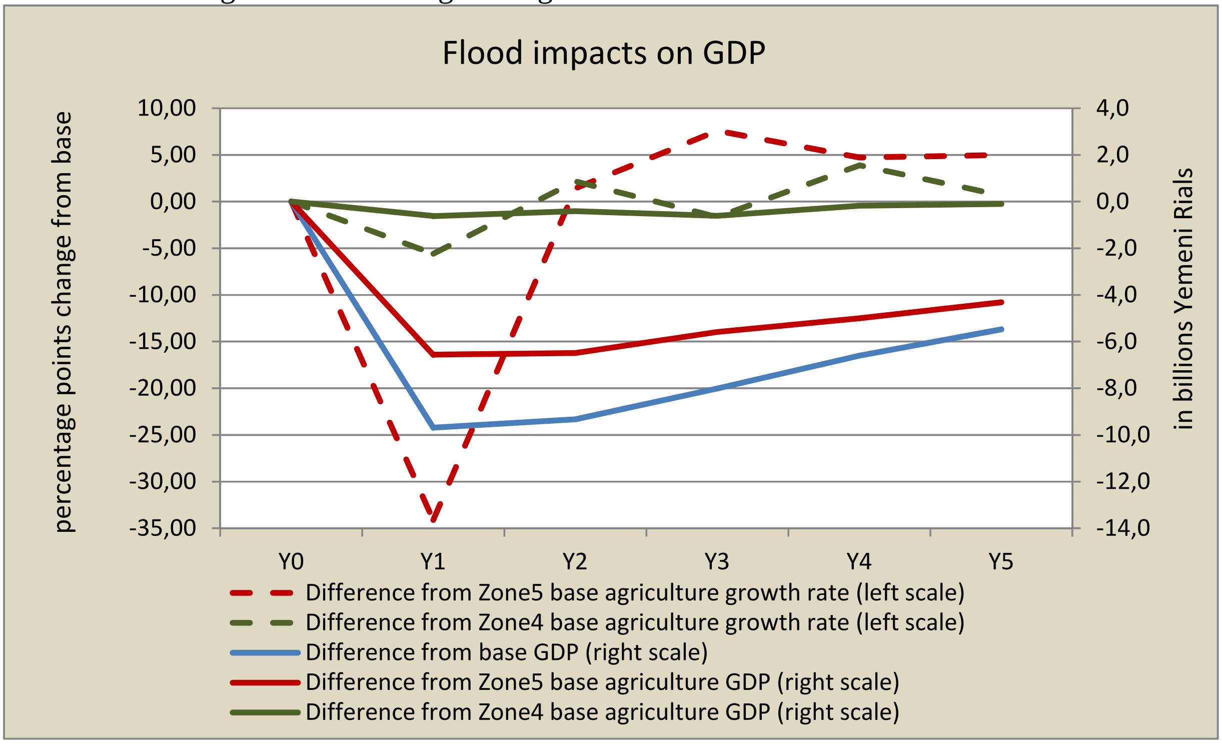
It is against these structural characteristics of the Yemeni economy and its households that the next sections analyze the potential impacts of the Hadramout flood.

4.2. Impacts of the Hadramout Flood

Agricultural activities of the Internal Plateau (zone 5) and the Arabian Sea Coast (zone 4) together contribute about 7 percent to total agricultural value added in Yemen, while the agriculture makes up about 8.5 percent of the country's GDP (Tables 3 and 4). Thus, any supply-side shock affecting agriculture in these zones will have only a modest impact on national GDP, but may have a substantial effect on the local economy. Yet, this does not mean that income losses are confined to those engaged in agriculture in the flood area. In fact, between 26 and 20 percent of total annual income losses occur outside the affected zones' agricultural sectors. The flood drastically changes the factor endowments in zones 4 and 5 with spillover effects to national goods and factor markets. Aggregate private consumption is reduced, driven by a loss of real incomes both through higher prices and loss of incomes from land, capital and labor. Demand for imports increases, especially for agricultural goods and food processing to substitute for previously domestically produced goods. Imported food and domestically produced food are not perfect substitutes, which leads to an increase in domestic food prices, albeit at lower levels than would be the case without international trade. Higher inflation leads to an appreciation of the real exchange rate, which discriminates against exports, and together with increasing imports leads to a worsening of the trade balance. Investment picks up over the whole period, reflecting the necessity to replace stocks that have been lost during flood.

As shown in Figure 2, real income losses in zone 5's agricultural sector range between 6.6 and 4.3 billion Yemeni Rials (YR) annually (33 and 22 million US$) during and in the aftermath of the flood; the losses are much lower (between 0.6 and 0.1 billion YR) in zone 4's agriculture. In the year of the flood's occurrence, agricultural value added in the two regions is 35 percentage points and 5 percentage points lower than without the flood, respectively. While growth rates pick up immediately after the shock, output remains lower throughout the whole period relative to a situation without the flood. The total cumulated real income loss over a period of 5 years amounts to 180 percent of pre-flood regional agricultural value added. Annual real income losses are slightly lower in total agriculture as lower wages in zone 5 induce outmigration into other zones' agricultural sectors. Total real GDP is between 6 and 10 billion YR lower than in a no-flood scenario, driven by general equilibrium repercussions resulting from falling incomes in affected zones and higher prices.

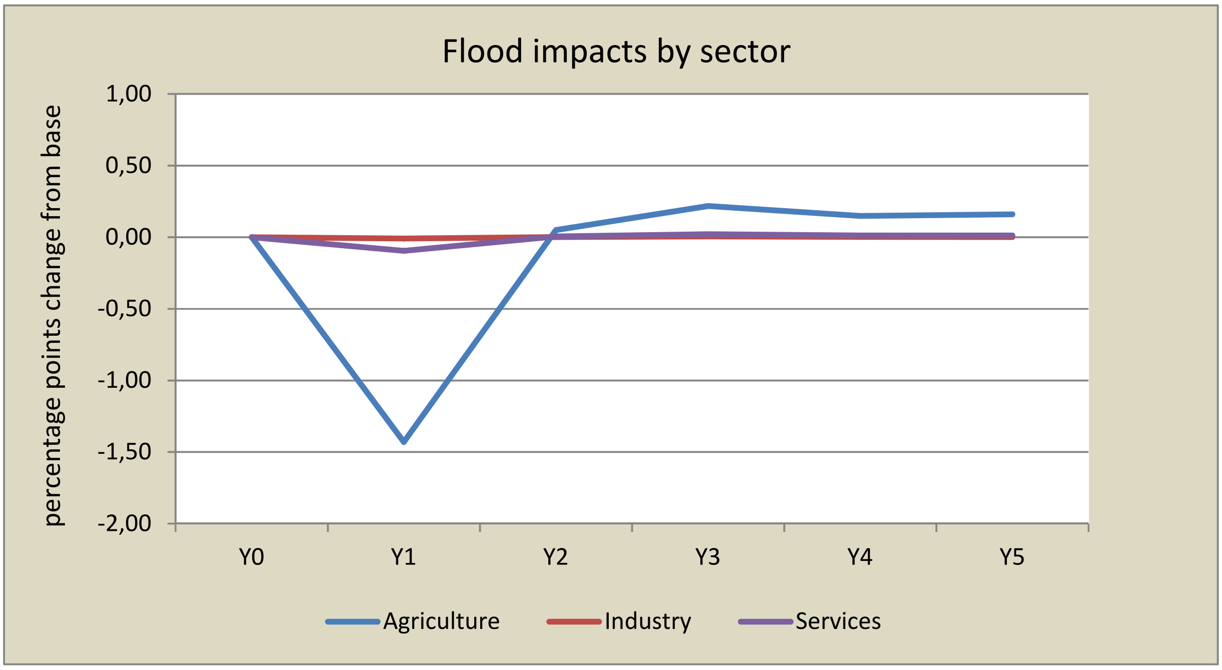
Figure 2: Loss in regional agricultural and overall GDP from flood



Source: DCGE Model

Agriculture is the sector hardest hit by flood whereas the industry and the service sectors are relatively more resilient (Figure 3). The loss in crop land and animals and the yield reductions in fisheries caused by the destruction of boats and fisheries equipment cannot be compensated by the resulting higher prices of agricultural commodities, which leads to a contraction in agricultural GDP growth. In the year of the flood, the service sector also slightly contracts due to a fall in aggregate demand. By contrast, model results suggest that industrial sectors – with the exception of food processing, which slightly contracts during the flood year and slightly expands afterwards – are hardly affected. This can be mainly explained by changes in factor rents. Floods force people to migrate out of agricultural and fishing activities seeking jobs in other sectors. This lowers the economy-wide wage rates, especially for low skilled labor. Industrial and service sectors that use this type of labor extensively benefit from the lower labor costs and so become more competitive.

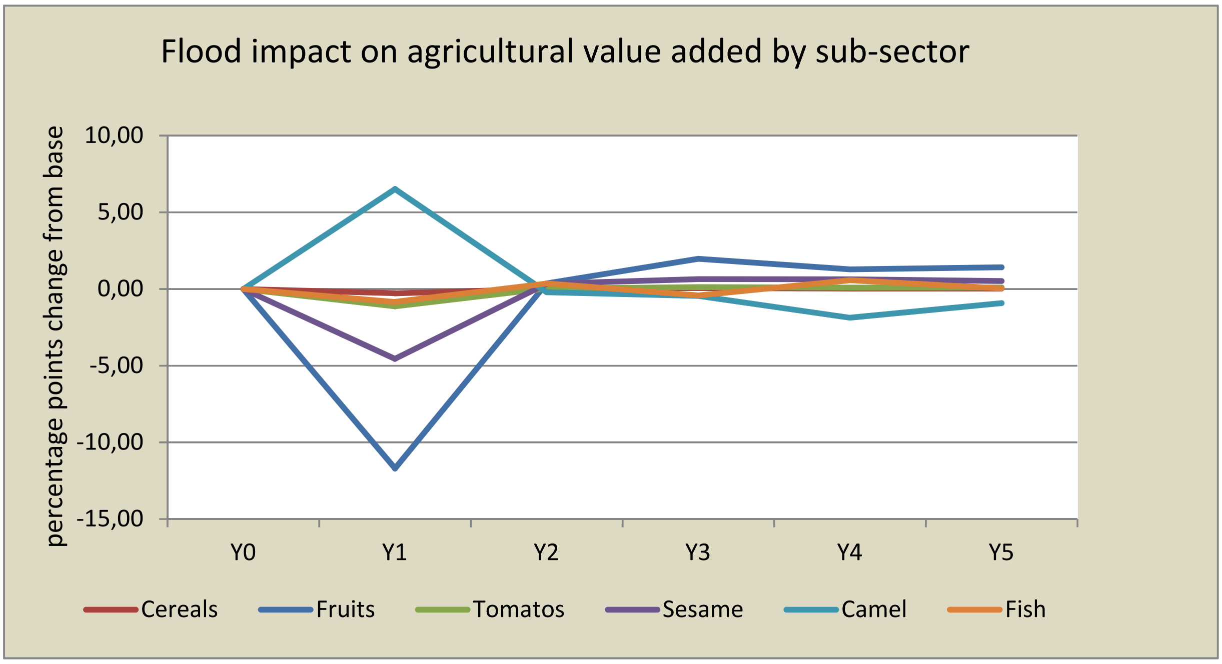
Figure 3: Flood impacts on GDP by sector



Source: DCGE Model

Within agricultural sub-sectors, fruits are the hardest hit by the flood, followed by sesame and tomatoes (Figure 4). Fruits make up about 45 percent of zone 5's value added (but only 1.5 percent in zone 4), followed by goats and sheep (about 20 percent), tomatos (10 percent), vegetables and camel (each about 7 percent), and sesame (3 percent), and given their high land intensity, fruits suffer more than other farm activities from the loss of soils and the uprooting of fruit trees. This is especially so during the flood year where value added for fruits falls by 11 percent from 2007 to 2008. Other crop activities, fishing and total livestock also contract during the flood but regain growth momentum over the longer run with the rehabilitation of agricultural land, replanting of fruit trees, restructuring of fishing infrastructure, and animal rearing. By contrast, camel production benefits from the flood. The reason is that camel production is the most export-oriented agricultural sector in Yemen; 70 percent of the camels are exported. As a result the domestic producer price for camel is largely determined on the world market. Moreover, the sector uses low-skilled labor very intensively. Thus, while the sector is hurt by the real-exchange rate appreciation in the base run, lower wages for unskilled labor accompanying the change in Yemen's factor endowment actually leads to lower real producer wages in camel production and provide an incentive to expand production, despite decreasing animal stocks. Yet, this result has to be interpreted cautiously as the model assumes fairly high factor substitution elasticities between, for example, camel stocks and unskilled labor.

Figure 4: Loss in agricultural GDP from flood by subsector

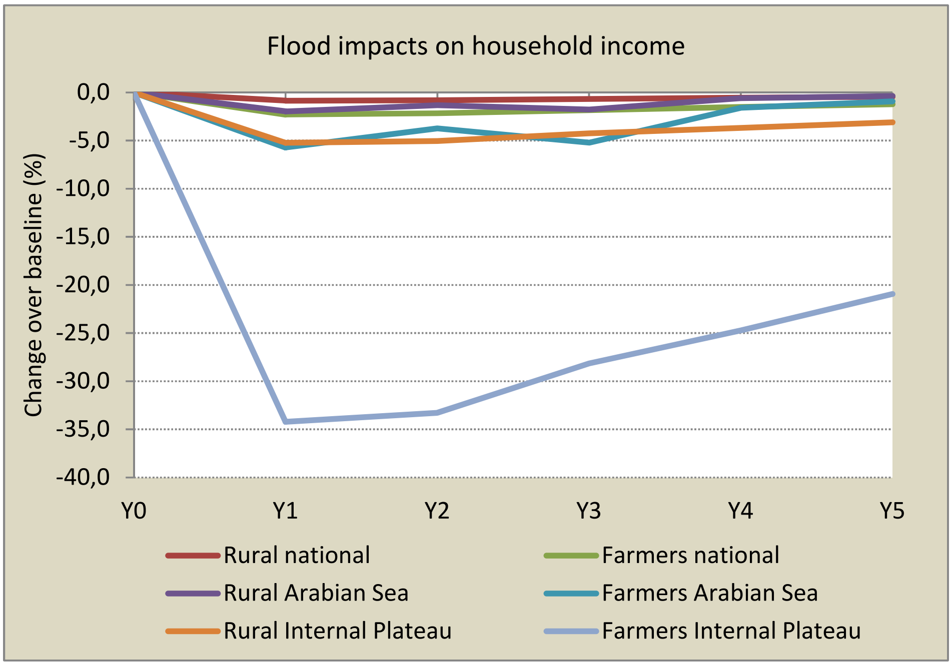


Source: DCGE Model

The impact of the 2008 flash flood on overall household income is minor. Accumulated overall income losses that result from flood damages and post-flood losses amount to about 2.5 percent of pre-flood GDP, reflecting the low contributions of, on the one hand, agriculture to GDP (8.4 percent) and the Internal Plateau and Arabian Sea Coast's combined contribution to agricultural GDP (30.3 percent), on the other. However, in the areas that are directly affected by the flood and the accompanying medium-run losses of agricultural capital and land, the consequences are severe and long lasting. Farm households in the Internal Plateau and, to a lesser extent, in the neighboring Arabian Sea Coast are hardest hit (Figure 5). In the Internal Plateau, household income of farmers is immediately falling by 35 percent and recovering only slowly; the immediate income loss of farmers is much lower in the Arabian Sea Coast but still reaches almost 6 percent. Moreover, the consequences for income generation are long-lasting in the flood areas. During the four years after the flash flood, income losses of farm households in the Internal Plateau remain high and decline only to 20 percent in the fifth year after the flood, compared to the baseline level. Overall income losses of farm households accumulate to 150 percent of their pre-flood annual income leading to accumulated regional and rural income losses of 18 and 23 percent of pre-flood income. In contrast, immediate income losses are lower and recovery is faster in the less affected Arabian Sea Coast so that rural and farm household incomes almost return to their pre-flood levels four years after the flood occurrence.

While the negative income effects are regionally concentrated, there are significant general equilibrium repercussions on household incomes in other regions as well. Accumulated household income losses in other regions range from 0.5 percent to almost 5 percent of pre-flood household income. As expected, farm households are the major losers with income losses ranging from 3.5 percent in the Upper Highlands to 5 percent in the Red Sea and Tihama Plain, while households, both rural and urban, farm and non-farm, in the Desert zone are almost unaffected by the flood because of low economic linkages to the flood-affected regions, both on the supply and demand side.

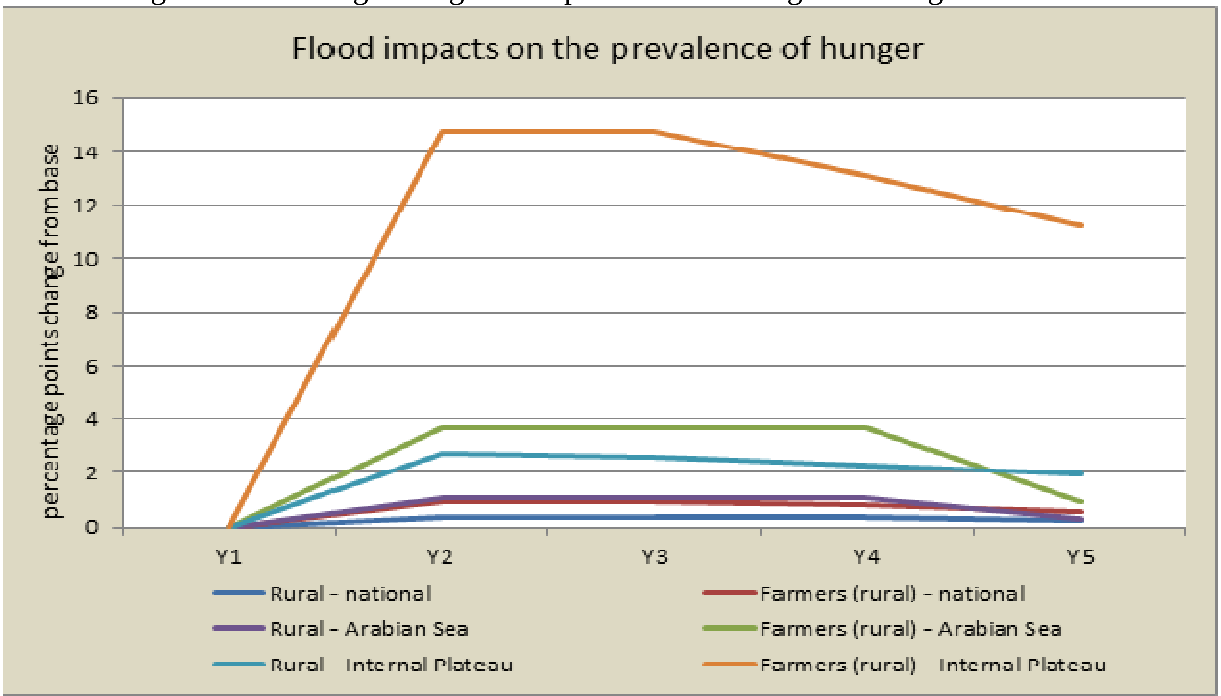
Figure 5: Percentage change in household income resulting from flood



The countrywide hunger impacts of the flood are also minor. Under the simulated flood scenario, the prevalence of hunger in Yemen's rural areas and among all Yemeni farmers rises by less than one percentage point compared to the baseline level (Figure 6). Yet, in the areas that are directly affected by the flood, the consequences are much more severe. Farm households in the Internal Plateau zone and, to a lesser extent, in the neighboring Arabian Sea zone are hardest hit. In the Internal Plateau, the percentage of hungry people living from farming surges by about 15 percentage points compared to a situation with no flood. This contributes to an increase in the overall prevalence of hunger in this zone by more than 2 percentage points in the years after the flood. Moreover, the consequences for food security are long-lasting in the flooded areas. During the four years after the flood year, the prevalence of hunger among farming households in the

Internal Plateau remains high and declines by only less than 4 percentage points, leaving still 11 percent more suffering from hunger in the fifth year after the flood compared to the baseline level. In contrast, recovery in the less affected Arabian Sea zone is faster so that the hunger prevalence almost returns to its pre-flood levels four years after the flood occurrence.

Figure 6: Percentage change in the prevalence of hunger resulting from flood



Source: Yemen DCGE Model and microsimulation model.

The pace of the recovery process depends on the structure of the local economy and the characteristics of the main economic activities. Farm incomes and thus farmers' food security are expected to be compromised over several years mainly due to the time required for the reconstruction of destroyed infrastructure and the rehabilitation of cropland and agricultural productivity. Given that many farmers earn large shares of their income from (perennial) fruit tree cultivation and as it takes several years until replanted fruit trees start bearing fruit, income losses and food insecurity extend over several years.

5. Concluding Remarks

The impact assessment of the October 2008 tropical storm and floods in the Wadi Hadramout has shown that agriculture is the sector hardest hit by floods. Estimates put the total cumulated real income loss over the period 2008-12 at 150 percent of pre-flood regional agricultural value added. The percentage of hungry people living from farming in the main flooding areas rises by about 15 percentage points in the year of the flood occurrence, and continues to stay well above pre-flood levels over the subsequent years. Regional spillover effects lead to temporary increases in hunger even in regions where the flood has no direct impact.

As concerns potential policy options, investments for reconstruction in the regions damaged by the flood may create income earning opportunities and generate a development push, which, however, provides only limited short to medium run benefits for the poor farming population. For this group, the negative medium-term impacts on real income and food sufficiency can be mitigated if farmers are enabled to replace the dead fruit trees with modern varieties of seedlings for fruit trees that start bearing fruits sooner than the traditional varieties. Since the potential for agricultural growth is not only constrained by recurrent floods but also by Yemen's general scarcity of water and arable land, the economy as a whole would benefit from accelerated structural change towards (rural and urban) non-farm activities. Policymakers can facilitate the generation of non-farm employment in various ways, e.g. by investing in infrastructure or human capital formation.

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Appendix 1: Determinants of Per Capita Calorie Consumption

Variable	Coefficient		Standard error
Log of expenditure	0.857	***	0.045
Log of expenditure squared	-0.057	***	0.004
log of household size	0.209	***	0.024
log of household size, squared	-0.061	***	0.006
Children	-0.186	***	0.012
Dependency ratio	-0.074	***	0.007
Adult man	0.042	***	0.016
Adult woman	0.077	***	0.026
Adult gender ration	-0.020	***	0.005
Log of household head's age	0.380	***	0.139
Log of household head's age, squared	-0.056	***	0.019
School attendance of household head	0.061		0.305
Education level of household head	-0.024	***	0.003
Qat consumption	-0.051	***	0.012
Share of qat expenditure on total expenditure	-0.014	***	0.004
Self-sufficiency level	0.122	***	0.025
Constant	3.852	***	0.21
Observations			12 093
F-value			69.76
R-squared			0.271
Adjusted R-squared			0.267

***Significant at the one percent level.