Exploring the Association between Agricultural Production Systems and Household Diets in Viet Nam

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Abstract

Viet Nam is an emerging economy going through a nutrition transition and facing a double burden of malnutrition. The government promotes an integrated and diversified production system that focuses on the symbiotic relationship of livestock, aquaculture, and fruits and vegetables (F&V), locally known as *Vuon Ao Chuong* (VAC). The expectation is that a VAC system can not only prevent soil degradation but also improve dietary quality and income. This study examines the correlation between VAC production systems and diets using cross-sectional data from the 2016 round of the Viet Nam Household Living Standards Survey (VHLSS). We model seven different outcomes: four continuous variables related to quantity consumed of fruits and vegetables, fiber, animal protein, and dietary energy; and three indicator variables related to whether diets are balanced in terms of intake of dietary energy derived from carbohydrate, proteins, and fats. While individual components of VAC, such as aquaculture and F&V production, show positive correlation with one or more of our dietary indicators, the adoption of the full VAC system is found to be positively correlated only with dietary fiber consumption, and this makes it difficult to prove the efficacy of the system in improving dietary quality. However, we find that several socioeconomic variables are positively correlated with one or more of the dietary indicators. These dimensions include access to markets, household wealth, household education level, and household size. Further research is needed to establish causal relationships, or lack thereof, between VAC system and diets by exploiting the panel structure of VHLSS to examine the role of VAC in promoting food and nutrition security in Viet Nam.

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1. Introduction

A healthy diet is essential for growth, development and maintenance of healthy bodily function (WHO, 2019a). Consumption of different food items such as cereals, legumes, fruits and vegetables (F&V), and animal sourced food (ASF) helps prevent several non-communicable diseases (NCD) including heart disease, diabetes, and cancer. General dietary recommendations include consumption of at least 400 grams per day (g/day) of F&V, with sugar and fat intake below 10% and 30% of total dietary energy consumption (DEC) respectively, and salt intake below 5 g/day (WHO, 2019b).

In this regard, agricultural production can enhance food and nutrition security directly, by improving food availability among subsistence producers, and indirectly, by enhancing the purchasing power of commercially oriented producers. Diversification of agricultural production into nutrient-rich plant-based foods and ASF, a commonly used indicator of food and nutrition security (Hoddinott and Yohannes, 2002; Kennedy et al., 2010; Malapit et al., 2013; Swindale and Bilinsky, 2006), is among the policy options being pursued to tackle micronutrient deficiency, as greater diversity in production is shown to be correlated to higher diversity in consumption. While the extent to which production diversity leads to improved dietary quality is an empirical question, several studies in Africa and South East Asia have documented a positive relationship between the two (Jones, Shrinivas, & Bezner-Kerr, 2014; Sibhatu, Krishna, & Qaim, 2015).

This study examines the correlation between agricultural production system and diets in Viet Nam. Since the enactment of Viet Nam's *Doi Moi* (renovation) policy in 1986, Viet Nam has committed to increase economic liberalization and enact structural reforms needed to modernize the economy and produce more competitive, export-driven industries (CIA, 2016). It has accomplished momentous progress in poverty reduction since the market reform. The share of population living below the international poverty line of $3.20 per capita a day at 2011 Purchasing Power Parity (PPP) has declined from 13.4% to 8.8% from 2014 to 2016 (World Bank, 2018). The unemployment rate is currently 2.2%, one of the lowest in the world (World Bank, 2018).

Despite these remarkable achievements, Viet Nam still faces poverty and malnutrition, and this problem is pronounced among ethnic minorities who reside in mountainous and remote areas.

For example, the poverty rate among minority groups is reported to be significantly higher than that of the dominant *Kinh* ethnic group (Bertelsmann Stiftung, 2018). Despite the fact that the contribution of fat to DEC has increased by 38% between 2004 and 2014 at the expense of the share from carbohydrates and proteins, 10.8% of the population was undernourished between 2015-2017 (FAO et al. 2018).[1] The increasing reliance on energy dense foods has consequently resulted in an uptick in obesity and NCDs (Trinh Thi, Simioni, and Thomas-Agnan, 2018). Stunting and wasting rates among children under the age of 5 years were, respectively, 25% and 6% in 2017 (FAO et al, 2018). These statistics highlight the coexistence of under- and over-nutrition in Viet Nam, similar to general trends seen in many poor and emerging economies.

Key agricultural products include rice, maize, coffee, rubber, tea, pepper, soybeans, cashews, sugar cane, peanuts, bananas, pork, and poultry (CIA, 2016). Sixty-five percent of the population lives in rural areas, with the agricultural sector employing 15% of the entire country's workforce (CIA, 2016). Due to agricultural intensification and expansion, the cropped areas have expanded from 7.3 to 8.9 million ha between 1995 and 2014 (GSO, 2016). Cereal (overwhelmingly rice) yield has been steadily increasing for the last several decades, although it has declined slightly in recent years; in 2016 productivity stood at 5,448 kg/ha compared to 5,601 kg/ha in 2015 (World Bank, 2018).

To assess the correlation between production systems and dietary quality, we focus on a traditional Vietnamese small scale bio-intensive integrated agricultural production system, known locally as *Vuon Ao Chuong* (VAC) that has three components – *Vuon*: garden, *Ao*: fishpond, and *Chuong*: animal shed. The garden encompasses the production of various plants bearing fruits and vegetables; the shed includes livestock production; and, finally, the fishpond provides aquaculture production, mainly fish and shrimp. Each element of this production system is complementary, where the fishpond acts as a source of water and mud for the garden, thereby nourishing it; the garden provides feed for fish or livestock, in addition to F&V for human consumption; and the fishpond serves as a source of animal feed with animal refuse complementarily used as fish feed. Finally, livestock manure can be used to fertilize the garden. This symbiotic relationship is expected to help regenerate farm soil quality as well as increase and diversify income sources.

[1] Undernourishment is defined when habitual food consumption is insufficient to provide dietary energy levels that are required to maintain a normal active and healthy life of an individual (FAO et al. 2018).

Guided by FAO and WHO (2019) guidelines for measuring healthy diets, we use a number of complementary dietary indicators covering a wide range of nutrients and dietary balance. In addition, previous literature recognizes that "…dietary diversity is universally recognized as a key component of healthy diets" (Ruel, 2002), providing a normative indication that, overall, the higher the diversity, the healthier the diet. To adequately account for diversity, we analyze per capita consumption of fruits and vegetables, fiber, animal protein, and dietary energy and their correlates. Additionally, we look at the correlates of having a balanced consumption of carbohydrates, fats and proteins. For the purpose of this study, we assess balance based on dietary energy derived individually from carbohydrates, fats and proteins. For adults, 45-65%, 20-35% and 10-35% of dietary energy should be derived from carbohydrates, fats, and proteins respectively (Institute of Medicine of the National Academies, 2005).

While VAC adoption might be effective in regenerating soil quality and consequently improving environmental outcomes, our analysis finds that the relationship with nutritional outcomes is ambiguous. While we do find positive correlations between VAC production and some of our dietary indicators, most of these are found to be non-significant and of relatively small magnitude. Individual components of VAC – aquaculture production, livestock production, and fruits and vegetables production – are however found to have significant correlations and could thus indicate that the policy promoting a full VAC system (households producing all of the individual components) might have potentially been over-emphasized. The paper is organized as follows: Section 2 presents the existing literature on the relationship between agricultural production and healthy diets; section 3 provides some details on the methods and data used; section 4 discusses the empirical results; section 5 reports the inferential findings and, finally, section 6 concludes.

2. Literature

Several socioeconomic and demographic factors are correlated with dietary quality. For example, among Americans, observational and descriptive studies show that belonging to certain races (controlling for other socio-economic characteristics) is associated to better diet quality and, generally, adult diet quality improves with income (Hiza, Casavale, Guenther, & Davis, 2013; Kirkpatrick, Dodd, Reedy, Krebs-Smith, 2012). Similarly, higher education of the household head is found to improve household and individual-level dietary diversity in urban Burkina Faso (Becquey et al., 2012), and higher agricultural incomes and production diversification are associated to higher quality diets in Malawi (Jones, 2016). Further evidence from West Africa suggests that household socioeconomic status is positively associated with increasing intake of dietary energy, fat, sugars and protein, as opposed to other macronutrients (Bosu, 2015). Findings from Bangladesh suggest that intrahousehold gender dynamics and bargaining over resources affects individual dietary quality in the household (Rashid, Smith, & Rahman, 2011).

Market access can also have a significant effect on the types of foods that are accessible to the household (Koppmair, Kassie, & Qaim, 2017; Larsen & Gilliland, 2009). Where markets are incomplete and transaction costs are high, households with a more diverse production may have improved access to better-quality diets than those with a less varied and subsistence production. Commercialized households may have a higher likelihood of consuming diverse food than their subsistence counterparts (Jones et al., 2014; Sibhatu et al., 2015), with the likelihood potentially increasing with the level of market integration (Hirvonen & Hoddinott, 2017).

Healthy diets help to protect against malnutrition in all its forms and NCDs that can have a nutritional etiology (e.g. diabetes, heart disease, stroke, and cancer) (WHO, 2019a; FAO, WHO, 2019). Several dietary indicators have been proposed in the literature, including Household Dietary Diversity Score (HDDS) (Swindale & Bilinsky, 2006), Food Consumption Score (World Food Programme, 2008), and Diet Quality Index-International (Kim, Haines, Siega-Riz, & Popkin, 2003). However, these indicators inform only about whether specific food items or groups were consumed; they do not embed the associated quantities consumed, thus omitting an important dimension of food consumption intensity.

Empirical literature on food security and nutrition has been traditionally focused on either dietary energy and nutrient intake or dietary quality. Hoddinott (1999) lists a variety of food security indicators, ranging from household caloric acquisition to individual food intake and dietary diversity.

Several studies have consistently found that dietary diversity is a proxy of nutrient adequacy. For example, Arimond et al. (2010) showed that micronutrient inadequacy among women in reproductive age in a panel of five diverse, resource-poor countries (Burkina Faso, Mali, Mozambique, Bangladesh and the Philippines) is strongly correlated with food group diversity indicators. Consistently, using 11 countries included in the Demographic and Health Surveys (DHS), Arimond & Ruel (2004) show that dietary diversity is associated with nutrient adequacy and child nutritional status. However, they caution that "[…] Before dietary diversity can be recommended for widespread use as an indicator of diet quality, additional research is required to confirm and clarify relations between various dietary diversity indicators and nutrient intake, adequacy, and density, for children with differing dietary patterns". In South Africa, Steyn et al. (2006), using nationally representative data for children 1-8 years old, conclude that dietary diversity indicators are also proxies of micronutrient adequacy of the diet.

In this regard, the importance of fruit and vegetable (F&V) consumption cannot be overstated. F&V are a significant source of vitamins, minerals and dietary fiber (Kader, 2001), rich in phenols, flavonoids, and phytosterols, imparting essential bioactive compounds. F&V consumption is strongly linked with improved health outcomes (Ortega, 2006), with antioxidants contained in F&V proven to protect against age-related ailments (Steinberg, 1991). Routine and habitual consumption of F&V is also found to reduce the risk of several common cancers (oral, lung, stomach, and colon) (Steinmetz & Potter, 1991). Despite these benefits, many low- and middle-income countries (LMICs) exhibit concerningly low F&V consumption ─ less than five servings a day or 400g per day set by WHO. During 2002-2003, F&V consumption inadequacy (percentage of population with consumption lower than 400g/day) ranged from 36.6% (Ghana) to 99.2% (Pakistan) for men; and from 38.0% (Ghana) to 99.3% (Pakistan) for women. In Viet Nam the corresponding figures were 86.7% and 81.8% for men and women, respectively (Hall et al. 2009).

Protein is an important macronutrient that provides energy, supports cognitive function, and is necessary for building, maintaining, and repairing tissues, cells, and organs throughout the human body. Protein deficiency has been linked with several health risk factors, especially among pregnant women and children, eventually resulting in diseases such as marasmus and kwashiorkor in extreme cases. Severe protein deficiency is also linked with fatty degeneration of the liver and heart along with the degradation of the small bowel, leading to loss of absorption and digestion capacity (Muller & Krawinkel, 2005). While protein can be obtained from plants, animal sourced proteins are more digestible and usable by the human body (Ghosh, Suri, & Uauy, 2012).

3. Method

3.1. Data and variables

Data for this study come from the 2016 iteration of the Viet Nam Household Living Standards Survey (VHLSS 2016) that covered 3,133 communes/wards. VHLSS is representative at the national, region, urban/rural, and provincial levels and was implemented throughout the year. Household-level food consumption data for this study were collected based on 30-day recalls, along with other socioeconomic, demographic, and geographical variables constructed for the multivariate analyses. A nutrient analytic Food Composition Table (FCT) was developed by combining food consumption data from the VHLSS 2016 with Vietnamese FCT (National Institute of Nutrition 2007). Information on some food items[2] was not available in the 2007 FCT, and therefore we complemented it with the 2017 version of the FCT from the National Institute of Nutrition. Apart from the added food items, the nutrient composition of the food items was consistent between the 2007 and 2017 versions. Refuse factors were used to account for inedible portions from the relevant FCT. As proxies of agricultural potential and market access, we use precipitation and temperature data from the Copernicus Climate Change Service (European Commission, 2019) and travel time to the nearest market from Weiss et al. (2018).

3.2. Dietary indicators

Seven indicators are used to proxy dietary quality: per capita F&V consumption (g/day); per capita dietary fiber consumption (g/day); per capita animal protein consumption (g/day), per capita dietary energy consumption (kcal/day), and three indicator variables for whether the household has a balanced share of dietary energy from carbohydrates, fat, and protein consumption (recommended ranges are: 45-65%, 20-35%, and 10-35%, respectively). The choice of dietary indicators is primarily guided by WHO and FAO (2003), FAO and WHO (2019), WHO (2019b), Institute of Medicine of the National Academies (2005), and Viet Nam's food-based dietary guidelines (FAO, 2013).

General recommendations for a healthy diet include the consumption of a great variety of unprocessed or minimally processed foods; limited consumption of highly processed food and beverages; consumption of whole grains, legumes, nuts, and F&V; and consumption of small amounts of red meat and moderate amounts of other ASF such as eggs, dairy, poultry, and fish (FAO, WHO, 2019). Nevertheless, the exact make-up of a healthy diet varies depending on food items available, dietary customs, and individual characteristics such as age, sex, and degree of physical activity (WHO, 2019b), and health priorities of a particular group. For example, Viet

[2] Items include cashew, coconut, durian, grape, Indian jujube, mangosteen, mulberry, papaya, pineapple, plum, sapodilla, seasonings, soybean, sugar-apple, honey, rambutan, meat of goat/sheep, bee honey, silk cocoon, piglet and calf.

Nam's food-based dietary guidelines emphasize consumption of protein-rich foods from animal and plant sources (FAO, 2013).

Viet Nam is a major world producer of rice (Nguyen, 2017), with this commodity featuring quite heavily in the Vietnamese diet. This strong reliance on rice may potentially increase the incidence of macronutrient imbalances. Additionally, the government has a target balanced diet with carbohydrate, fat, and protein contributions, respectively, of 68%, 18%, and 14% of total DEC (Ministry of Health, 2012). This split amongst the macronutrients is similar to the breakdown we are using in our statistical analysis.

3.3. Statistical model

Since our focus is on the correlation between production systems and dietary quality, we estimate the model in Equation 1 on a sub-sample of households which reported agricultural production during the reference period.

$$Y_i = \alpha_o + \alpha_1 Rice_i + \alpha_2 Other_i + \alpha_3 Live_i + \alpha_4 Aqua_i + \alpha_5 F\&V_i + \alpha_6 Live\_F\&V_i + \alpha_7 Live\_Aqua_i + \alpha_8 Aqua\_F\&V_i + \alpha_9 VAC_i + \mathbf{B}'\boldsymbol{X}_i + \boldsymbol{\Omega}\boldsymbol{Z}_i + \epsilon_i \quad (1)$$

where i is an index for household; Y is one of the dietary indicators mentioned previously; $Rice$ is an indicator for whether the household produced *only* rice (omitted category); $Other$ is indicator for whether household produced any *other crops*[3] (both food and non-food) and no other VAC component, with/without rice; $Live$ is indicator for whether the household produced livestock and no other VAC component; $Aqua$ is indicator for whether the household produced aquaculture and no other VAC component; $F\&V$ is indicator for whether the household produced F&V and no other VAC component; $Live\_F\&V$ is indicator for whether the household produced livestock and F&V; $Live\_F\&V$ whether household produced livestock *and* F&V; $Live\_Aqua$ whether household produced livestock and aquaculture; $Aqua\_F\&V$ whether household produced aquaculture and F&V; VAC is indicator for whether the household produced livestock, aquaculture, and F&V. All categories except the first two (*Rice* and *Other*) are defined to include households with or without rice or other crops. Indicators for the different production systems are defined such that the categories are mutually exclusive.

[3] These other crops category includes primarily industrial and staple crops, such as: soybean, peanuts, sesame, sugarcane, tobacco, cotton, ramie, sedge, tea, coffee, rubber, pepper, coconut, mulberry, cashew, maize, cassava, etc.

The matrix $\boldsymbol{X}$ contains household-level socioeconomic conditioning variables, including household size (number of household members unadjusted for adult equivalent scales), area of residence (urban/rural), gender and education of the household head, asset-based household wealth index[4], total agricultural production value (in the past 12 months, measured in thousands of D*ong*), market access (measured as time taken in minutes to travel to the nearest market), and the ratio of purchased food in the household's total food value (percent of food by value that is purchased). The matrix $\boldsymbol{Z}$ includes the historical mean and coefficient of variation of precipitation and temperature between 1995 and 2015, as they are likely to affect availability and accessibility of food. The model error term is expressed by ϵ_i.

Ordinary Least Squares (OLS) model is estimated when the dependent variable is a continuous variable measuring the quantity consumed of F&V consumption, fiber, animal protein, or dietary energy. A logit model (assuming ϵ_i to follow a logistic distribution) is estimated when the dependent variable is a binary outcome measuring whether the household has a balanced dietary energy derived from carbohydrates, fats, and proteins. All regressions and descriptive summaries are weighted using survey weights, and standard errors have been clustered at the stratum level. Additionally, for the logistic specification, we are presenting the marginal effects.

4. Results

Table 1A shows the sample distribution by production system. Approximately 40% of the sample are non-producers. A full VAC model of production including all the subcomponents (F&V, aquaculture and livestock) is implemented by only 8.6% of the sample. Livestock with F&V and livestock-only are the two most common VAC components (21.1% and 11.2% of households, respectively).

Table 1A: Sample distribution by production system (weighted)

Production Category	Count	Frequency	Cumulative
Non-Producer (does not produce rice, VAC crops or other crops)	9,418,948	38.11	38.11
Rice only (produces only rice, but no other crops and no VAC crops)	1,216,244	4.92	43.04
Other crops (no VAC crops, with/without rice)	768,391	3.11	46.15
Livestock (with/without rice/other crops)	2,768,769	11.20	57.35

[4] The wealth index was constructed using factor analysis (principal-component factor method) following Filmer & Pritchett (2001), based on durable household assets and dwelling condition proxied by the quality of water, toilet, and dwelling construction materials.

Aquaculture (with/without rice/other crops)	649,817	2.63	59.98
F&V (with/without rice/other crops)	1,734,649	7.02	67.00
Livestock and F&V (with/without rice/other crops)	5,207,048	21.07	88.07
Livestock and Aquaculture (with/without rice/other crops)	495,102	2.00	90.07
Aquaculture and F&V (with/without rice/other crops)	339,753	1.37	91.45
VAC (with/without rice/other crops)	2,113,431	8.55	100.00
Total	**24,712,152**	**100.00**	

Limiting our sample of interest (as we will do for our estimation results) to households which are involved in production, Table 1B presents the same results as Table 1A:

Table 2B: Sample distribution by production system (weighted; producers only)

Production Category	Count	Frequency	Cumulative
Rice only (produces only rice, but no other crops and no VAC crops)	1,216,244	7.95	7.95
Other crops (no VAC crops, with/without rice)	768,391	5.02	12.98
Livestock (with/without rice/other crops)	2,768,769	18.10	31.08
Aquaculture (with/without rice/other crops)	649,817	4.25	35.33
F&V (with/without rice/other crops)	1,734,649	11.34	46.67
Livestock and F&V (with/without rice/other crops)	5,207,048	34.05	80.72
Livestock and Aquaculture (with/without rice/other crops)	495,102	3.24	83.96
Aquaculture and F&V (with/without rice/other crops)	339,753	2.22	86.18
VAC (with/without rice/other crops)	2,113,431	13.82	100.00
Total	**15,293,204**	**100.00**	

Table 2 panel A presents a descriptive summary for the full sample as well as separately for non-producers and producers, along with significance levels from tests of equality of means across groups. Average household size is 3.7 members, household head age is over 50 years, female-headed households are about a quarter of the total, residential area covers about 80 square meters (m^2), a third of the sample resides in urban areas, and average travel time to the nearest market is approximately 35 minutes. Producers are more likely to live in larger households, be male-headed, and travel longer to the nearest market, while they are less likely to fall in the upper education levels or to reside in urban areas. Finally, we observe a significant difference in the average wealth status between producers and non-producers, with the latter being significantly worse off.

Table 3: Descriptive summary

Variable	Mean Full Sample	Mean Non-Producers	Mean Producers
N (unweighted)	9,399	3,209	6,190
(A) Independent Variables			
Socio-economic			
Household size	3.74	3.47***	3.93***
Household head age	52.09	52.92***	51.06***
Female household head	0.26	0.37***	0.19***
Most common household education level			
None	0.16	0.14***	0.18***
Primary	0.23	0.19***	0.27***
Lower Secondary	0.29	0.21***	0.32***
Higher Secondary	0.20	0.24***	0.17***
College and above	0.12	0.21***	0.06***
Urban	0.32	0.21***	0.06***
Household residential area (m^2)	79.7	83.09***	78.18***
Household Wealth Index	0	0.30***	-0.26***
Nearest Market (minutes)	34.77	30.85***	45.58***
Agriculture			
Total agricultural land (hectares)	2.95	0.00***	5.02***
Number of food groups produced	1.75	0.00***	2.85***
Number of food items produced	3.14	0.00***	5.21***
Household produces livestock	0.43	0.00***	0.70***
Household produces fish or shrimp	0.15	0.00***	0.25***
Household produces fruits or vegetables	0.38	0.00***	0.62***
Total production value (‘000 *dong*)	19631.3	0.00***	26715.85***
Assets and income			
Number of different kinds of durable goods	11.84	12.73***	10.98***
Total expenditure (per capita)	37603.44	50112.11***	26954.54***
Biophysical (1995 - 2015)			
Mean annual temperature (degree Celsius)	24.96	25.46***	24.42***
CV temperature	0.13	0.11***	0.14***
Mean monthly precipitation (mm)	163.17	168.30***	165.57***
CV precipitation	0.79	0.78***	0.80***
(B) Dependent Variables			
Fruits & Vegetable consumption (g/day/per capita)	70.49	82.43***	68.36***
Fiber consumption (g/day/per capita)	3	2.99***	3.09***
Protein from animal origin (g/day/per capita)	18.82	20.93***	19.18***
Dietary energy consumption (including FAFH) (kcal/day/per capita)	2,408.83	2,546.13***	2,440.77***
Proportion of calories from carbohydrates (%)	68.8	66.64***	69.71***
Proportion of calories from protein (%)	12.8	13.39***	12.41***
Proportion of calories from fats (%)	16.4	17.95***	15.64***

*** p < 0.1, ** p < 0.05, *** p < 0.01**

An average Vietnamese household produces about 1.75 food groups[5] and slightly more than 3 unique food items, with 43%, 38%, and 9% of households producing livestock, F&V, and fish or shrimp, respectively. Total annual production value is estimated at 19.6 million *dong*. On average, households possess about 12 unique durable assets, and have total per capita expenditure above 37.6 million *dong*. Producers seem to be worse off than non-producers along several dimensions.

Viet Nam is divided into the highlands and the Red River Delta in the north, and the Central Mountains, the coastal lowlands in the central region, and the Mekong River Delta in the south. A dip in elevation from the northwest to the southeast exists, along the two major rivers: The Red River and Mekong River. They flow in the northern and southern regions, respectively, being an important source of soil and nutrients for agricultural land. Arable land is however limited, being only 20% of the total land. Soils are quite diverse in the country: the three main soil groups are mountainous, hilly, and delta soils. Mountainous and hilly soils tend to be acidic, degrade quickly, and exhibit poor fertility. In contrast, soils in delta regions are primarily alluvial, highly fertile, and are suited for extensive cultivation (Babatunde et al. 2016). Mean annual temperature in the country was approximately 25 degrees Celsius during the 20 year period 1995-2015, with an average monthly precipitation of approximately 163mm. Variability of precipitation is greater than temperature's although, given the shape of Viet Nam territory, variability varies quite substantially according to the diverse agro-climatic zones. As with socioeconomic variables discussed above, temperature and precipitation are also found to differ statistically by producers and non-producers, indicating that the two groups are clustered in different areas of the country. This is unsurprising, as we would expect producer households to live in higher agricultural-potential regions than non-producers, the latter living predominantly in urban areas.

Table 2 panel B shows average values of dietary indicators across the two household groups. Average F&V consumption in Viet Nam is approximately 70g per day per capita, while protein consumption from ASFs averaged slightly less than 20g per day per capita. The share of dietary energy (kcal) obtained from carbohydrates, protein, and fats averaged approximately 69%, 13%, and 16%, respectively. Significant differences in the dietary patterns of producers and non-

[5] The food groups considered (and defined as per VHLSS documentation) are the following: (1) rice, (2) staple food crops, non-staple food crops and other annual crops, (3) annual and perennial industrial crops, (4) fruit trees, (5) animal husbandry, hunting, trapping and domesticated birds, (6) fishery.

producers can be found. While producers show a higher caloric intake when food away from home (FAFH) is excluded, its inclusion reverses the result in favor of non-producers. This again signals that non-producers tend to be concentrated in urban areas and thus enjoy greater access to FAFH. Non-producers also derive a higher share of their caloric energy from proteins and fats, pointing towards their relatively higher economic status, with consequent uncertain nutritional implications.

Figures 1 through 6 show the difference across certain socioeconomic and demographic dimensions based on the production categories defined previously (Table 1B). This comparison would provide valuable descriptive findings, helpful for interpreting the estimation results.

Figure 1: Household size, by production category

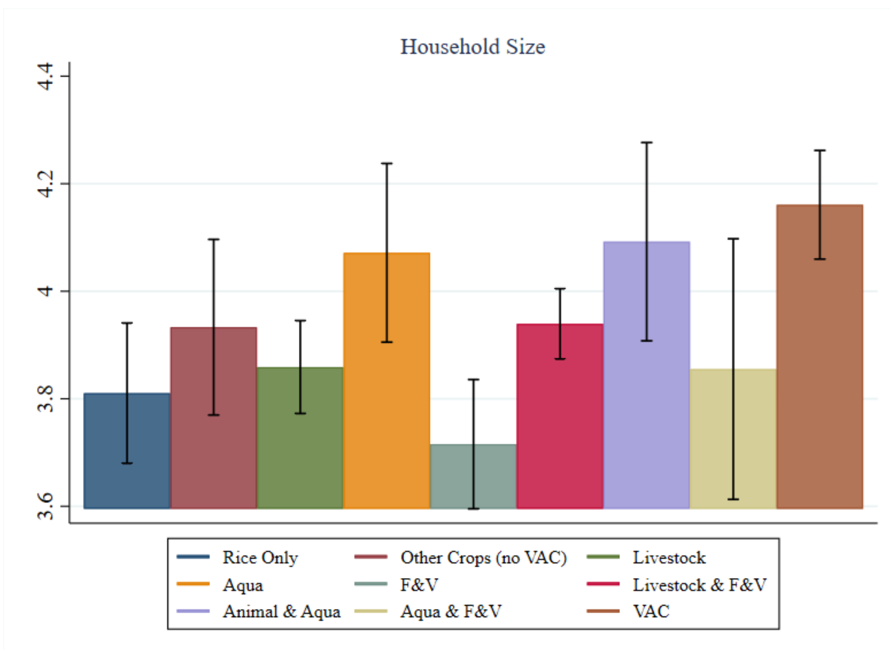


Figure 1 shows a considerable variability of household size across production groups. While only some of the differences are statistically significant, rice-only producing households show relatively lower household size, whereas households engaged in VAC production tend to be larger, signaling possible differences in per capita expenditures between these two categories.

Figure 2: Household wealth index, by production category

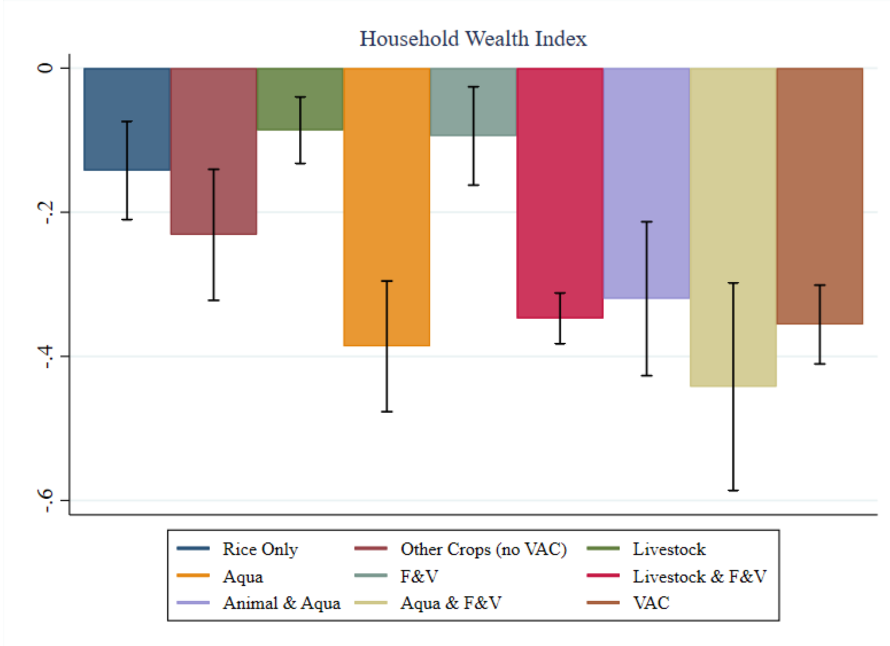
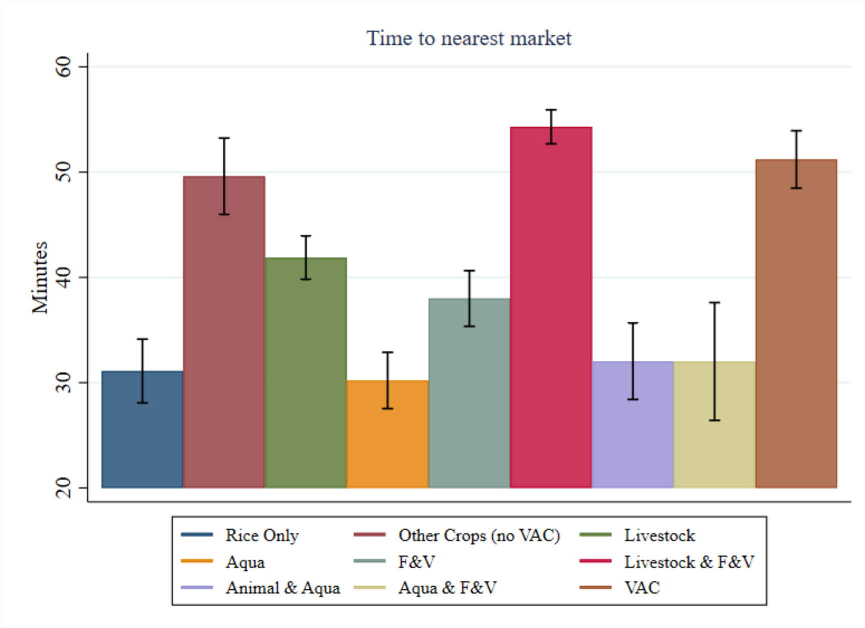


Figure 2 shows the distribution of the household wealth index across production categories. From Table 2 we know that producers are, on average, worse off than non-producers. Hence, since the index was constructed based on the entire sample, values of wealth index for each category reported in Figure 2 is negative. As with the earlier figure, while considerable differences in average wealth across producers exist, significant differences are present only for few categories. However, average value and confidence intervals for rice-only producers are higher than the confidence intervals for VAC producers, suggesting that the latter are worse off, supporting our hypothesis from the previous figure.

Figure 3: Market access, by production category



Based on Figure 3, VAC producing households travel for a longer time to access the nearest market, relative to rice-only producing households. This could indicate that VAC households are located in relatively more remote locations, making it more difficult for them to participate in market activities. Their reduced market participation, in conjunction with relatively lower household wealth, could mean that they have greater difficulty in procuring more diverse, nutritious food.

There are no significant differences in agricultural land size cultivated between rice-only and VAC producing households (Figure 4). While the relatively large endowment of agricultural land is expected for households specializing in rice production, this finding runs counter to what we might expect for VAC producing households, as they are expected to be relatively poor (based on the wealth index), small scale producers.

Figure 4: Agricultural land size, by production category

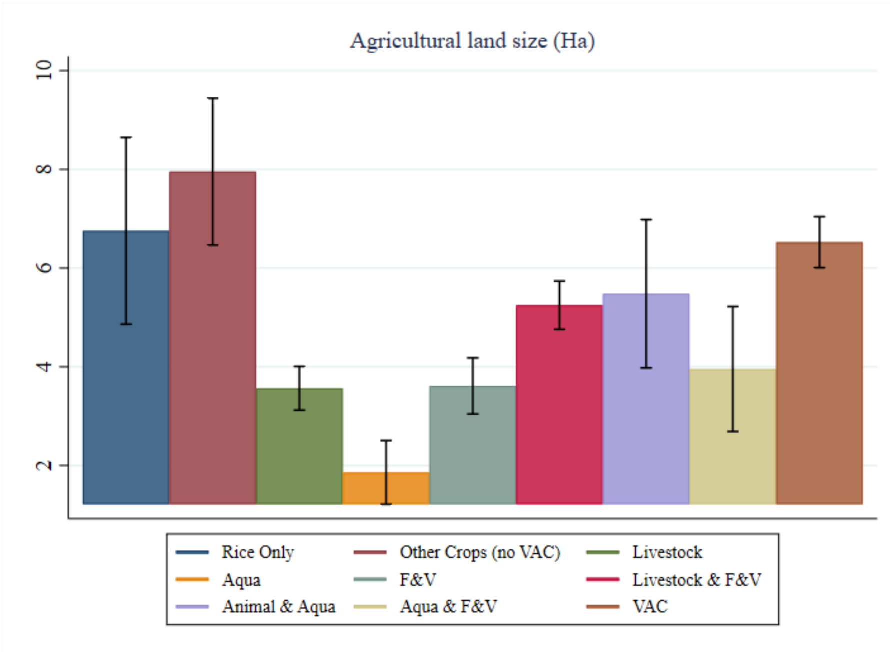
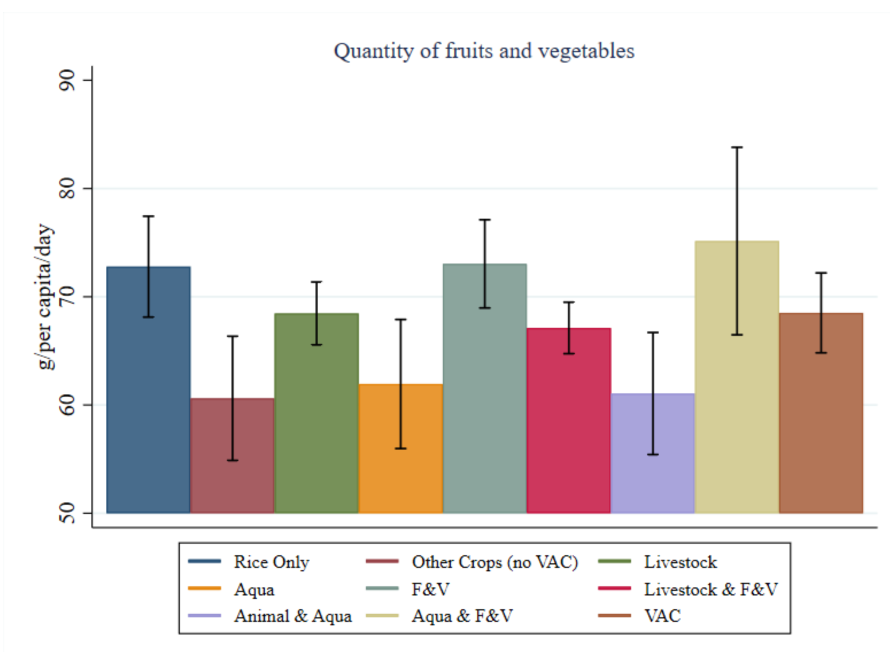


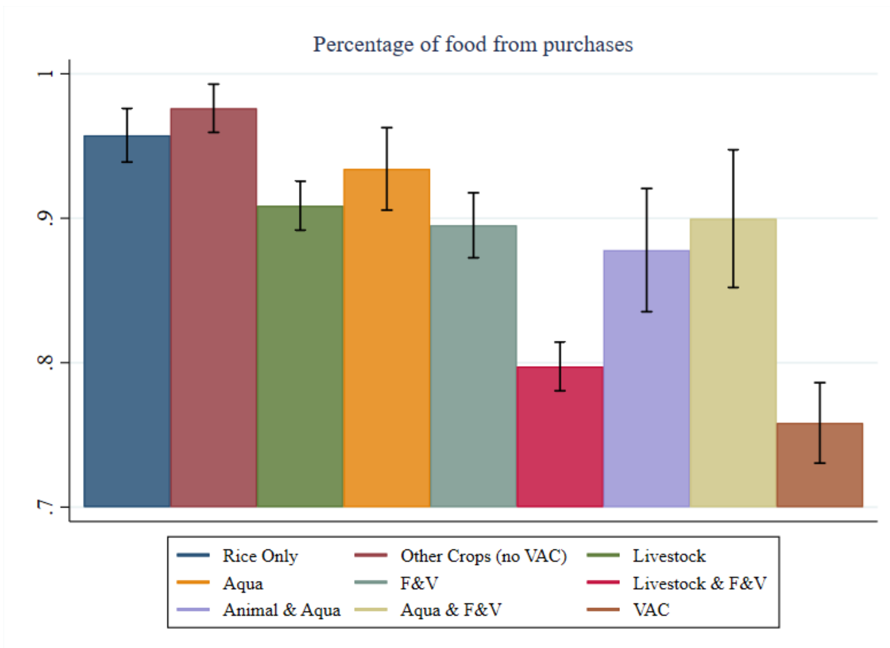
Figure 5 breaks down the consumption of F&V consumed by production categories. In line with previous figures, while there are considerable differences in average values, they tend to be non-significant, especially for production categories defined by the joint production of two or more VAC components. Furthermore, there is no statistically significant difference between VAC producers and rice-only producers.

Figure 5: Fruit &Vegetable consumption, by production category



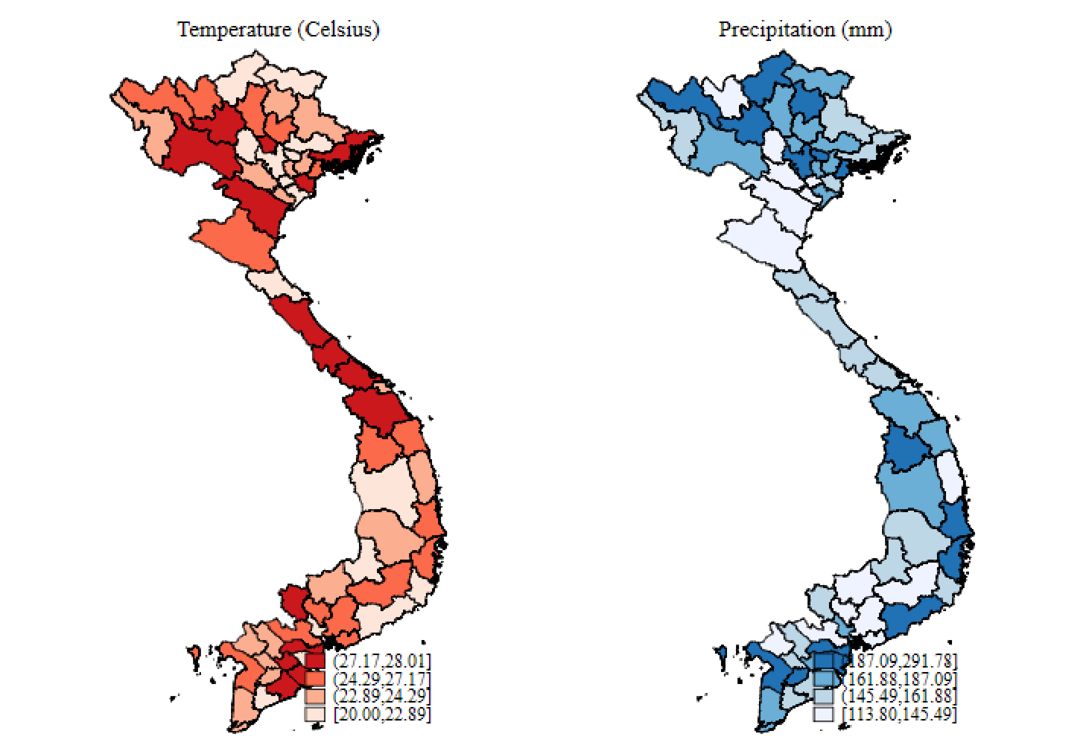
Finally, Figure 6 shows the difference in the share of food (expressed in monetary value) derived from purchases. Rice-only producers derive a substantially and significantly larger share of their food from purchases, as opposed to households engaged in VAC production. This result could be explained by the fact that rice specializers are on average better-off, with lower household size, higher land size, and higher market access, hence more likely to interact with the market in order to obtain a relatively higher variety in their diet. Similarly, since VAC producers grow a mix of F&V, aquaculture, and livestock, they have lower need to purchase food from the market. Additionally, Figure 3 confirmed that VAC households also show the highest travel time to the nearest market, further hampering their opportunities for food purchases.

Figure 6: Share of food from purchases, by production category



From the above figures we can conclude that rice-only producing households are fundamentally different from VAC producers (or households producing two or more individual VAC components). The latter are on average poorer and have lower access to markets. Since our comparisons have been unconditional on any characteristics that could affect the difference between the two groups, we will be able to qualify the descriptive findings obtained so far using multivariate econometric techniques. The latter will control for confounding factors mediating the relationship between outcome variables and production systems, contextualizing the potential success (or lack thereof) of the VAC production system in relation to better dietary outcomes.

Figure 7: Spatial variation of temperature and precipitation (average by province)



Source: Copernicus Climate Data (ECMWF ERA5 monthly averaged data on single levels (1995 to 2015))

Figure 7 illustrates the spatial variation of temperature (left panel) and precipitation (right panel). Climate is diverse across the country, with three broad regions - humid and subtropical in the north, tropical monsoon in the center, and tropical savannah in the south. High levels of humidity prevail throughout the year, ranging between 84 and 100 per cent. Monthly precipitation ranges from 114 mm to 292 mm. Average temperatures range between 21 and 27 degrees Celsius and are higher in the southern areas of the country. The southern regions show both the highest average temperature and highest rainfall. More generally, substantial variation across regions and provinces for both rainfall and temperature occur. Biophysical variables are strongly spatially correlated to different household production activities.

Table 3 shows unconditional pairwise statistical correlations across our dietary indicators. Results reported are in line with the nutrition literature, e.g., fiber consumption showing positive correlation with F&V consumption; proportion of dietary energy from protein positively correlated with animal protein; proportion of dietary energy from carbohydrates negatively correlated with both F&V consumption and animal protein consumption.

Table 3: Correlation between dietary indicators

	Fruits and Vegetable consumption (g/day/ capita)	Fiber consumption (g/day/per capita)	Protein from animal origin (g/day/ capita)	Dietary energy consumption (including FAFH) (kcal/day/ capita)	Proportion of calories from carbohydrates (%)	Proportion of calories from protein (%)	Proportion of calories from fats (%)
Fruits and Vegetable consumption (g/day/per capita)	1						
Fiber consumption (g/day/per capita)	0.71	1					
Protein from animal origin (g/day/per capita)	0.37	0.35	1				
Dietary energy consumption (including FAFH) (kcal/day/per capita)	0.25	0.39	0.35	1			
Proportion of calories from carbohydrates (%)	-0.32	-0.06	-0.51	-0.06	1		
Proportion of calories from protein (%)	0.33	0.06	0.62	0.03	-0.63	1	
Proportion of calories from fats (%)	0.28	0.03	0.41	0.03	-0.88	0.54	1

Figure 8 below illustrates the spatial distribution of dietary energy consumption across regions (left panel) and provinces (right panel)[6]. Areas with the highest calorie consumption also show the highest rice production (e.g. the Mekong Delta). Interestingly, there is positive correlation between calorie consumption and precipitation in the southernmost and northernmost regions of the country, as this pattern is consistent with higher precipitation supporting greater food production, thus enabling greater consumption.

[6] Please note that values by region and province show different ranges, according to the differential variation across spatial levels.

Figure 8: Spatial variation in dietary energy consumption

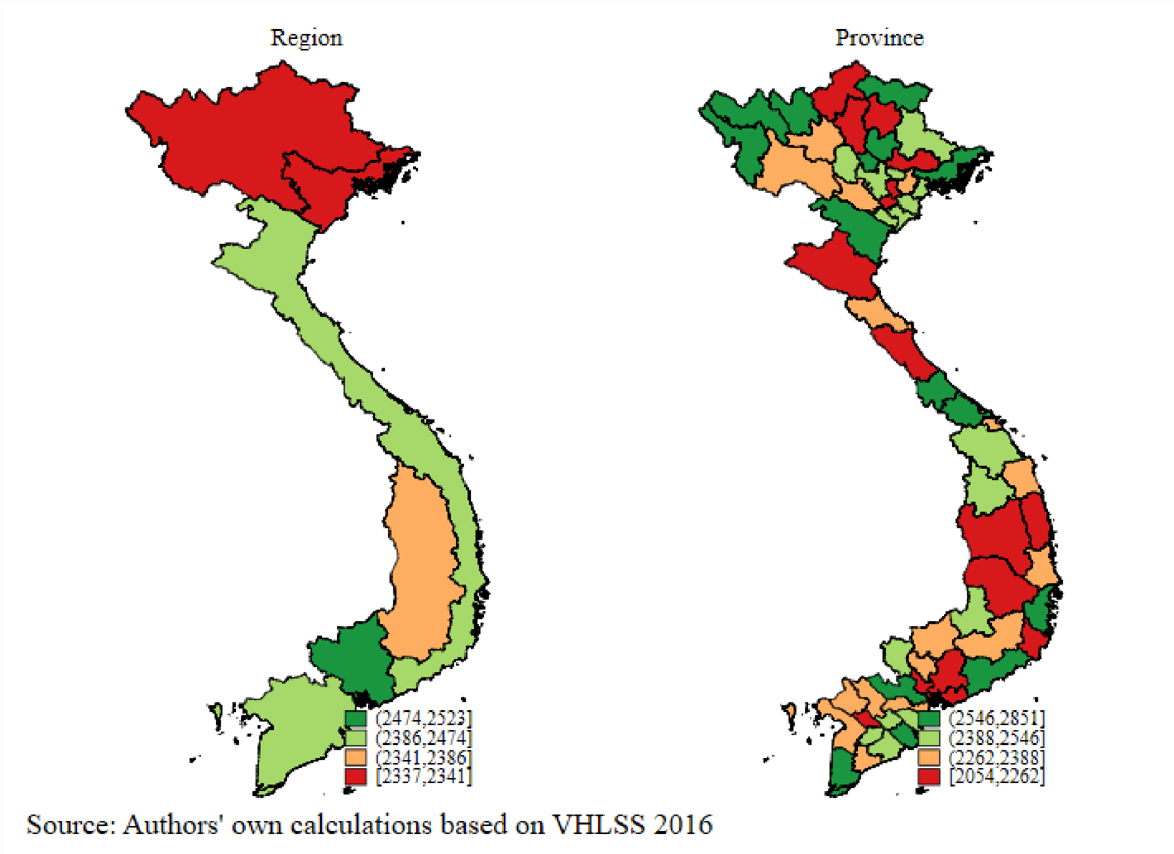


Table 4 and Table 5 show results from OLS and logit regression models, respectively. Larger households seem to have worse diets using the different continuous measures of dietary quality; for one additional household member F&V consumption reduces by 9.8 g/per capita/day, fiber consumption reduces by 0.26 g/per capita/day, animal protein consumption reduces by 2.2 g/per capita/day, and dietary energy consumption by 155 kcal/per capita/day (Table 4). While the gender of the household head does not have any significant association with kilocalorie consumption, there is a positive correlation between residing in a rural location and the amount of dietary energy consumed, associated with an increase of 86 kcal/per capita/day. Compared to the base level of no education, higher education levels are significantly positively correlated with greater level of the indicators considered. However, this trend is not uniform, with the higher secondary education level having a significant correlation only for dietary energy and not the other indicators. Additionally, the magnitude of the point estimates is smaller than for household size, suggesting that the latter has a stronger association with our dependent variables than the education level. Household wealth is highly (1% level) significant and is positively correlated with all dietary indicators, suggesting that wealthier households have access to higher quality food, unsurprisingly. Total production value (measured in millions *dong*) is significantly positively correlated with fiber, animal protein, and dietary energy consumption, with a unit increase being associated with very small increases of 0.003 g/per capita/day, 0.03 g/per capita/day and 2.3 kcal/per capita/day. respectively. The limited magnitude suggests that while production system is associated to a statistically significant correlation, it is nonetheless negligible.

Given the mutually exclusive production categories, rice-only producing households were taken as our reference category. Therefore, parameters associated to each production category need to be interpreted relative to rice-only producers. Households producing *other crops* (and no VAC component) actually consume less animal protein (by 1.5 g/per capita/day) and dietary energy (by 115 kcal/per capita/day) relative to rice-only producing households. The relatively lower dietary energy consumption can be explained by the fact that specialized rice producers would have greater rice consumption, which is relatively high-energy dense. While production of F&V has a negative correlation with consumption of animal protein (by 1.2 g/per capita/day), aquaculture production is significantly positively correlated with animal protein (by 2.4 g/per capita/day), mostly due to fish and shrimp. Surprisingly, production of livestock alone or in conjunction with aquaculture or F&V does not seem to be significantly associated with ASF consumption.

Dietary fiber is mostly derived from F&V (Mayo Clinic, n.d.; U. S. Department of Health and Human Services, n.d.), and households producing F&V and livestock and those producing F&V and aquaculture are more likely to consume fiber (0.17 and 0.35 g/per capita/day, respectively) relative to rice producers. However, we observe that rice-only producers already report a relatively high consumption of F&V, as shown in Figure 5.

Adoption of all three VAC components -that is, aquaculture, livestock, *and* F&V- is significantly positively correlated only with fiber consumption (by 0.29 g/per capita/day). While parameter estimates associated to the other dietary indicators are positive, they are not significant, suggesting that full application of the VAC production system may not be essential for improving nutrition. However, some VAC components do show significant positive associations (e.g., aquaculture and F&V with both F&V and fiber consumption; livestock and F&V with F&V and fiber consumption; both aquaculture and F&V with ASF consumption).

Market access, measured as the amount of time taken to travel to the nearest market, is however found to be significantly negatively correlated with F&V consumption (by 0.21 g/per capita/day) and animal protein consumption (by 0.02 g/per capita/day), but positively correlated with dietary energy consumption, though with negligible elasticity (by 1.9 kcal/per capita/day), indicating that remote households might be just slightly disadvantaged in accessing nutritious food and hence tend to consume more staples.

Looking at the second set of dependent variables (Table 5), we find that an increase in household size significantly reduces the probability of deriving a balanced proportion of dietary energy from macronutrients, with a reduction by 4.8%, 3.8% and 0.6% for carbohydrates, fats, and proteins, respectively. Unlike the earlier cases where there was no statistically significant correlation with female household headship, we find that female-headed households are 4.6% more likely to derive a balanced proportion of dietary energy from fats, potentially indicating that women might make better dietary choices when they are the main decision-makers in their household, supporting previous research (Amugsi et al. 2016; Rogers 1996). Surprisingly, the direction of the correlation of education and wealth are opposite. While education levels are significantly negatively correlated with balanced dietary energy from carbohydrates and fats, household wealth is found to be significantly positively correlated with balanced dietary proportions for all macronutrients considered. Unlike the previous OLS regression estimates, where we find some positive correlations between production categories and outcome variables, the latter estimates report mostly negative associations. Perhaps more concerningly, the significant coefficients associated to VAC adopters are negative, suggesting that this production system reduces the probability of consuming a diet with balanced proportion of carbohydrates and fats. As found before, the separate VAC components show differential associations: producers of livestock and aquaculture are more likely to attain balanced carbohydrate consumption, though less likely to reach balance in fat consumption; producers of aquaculture and F&V are less likely to achieve balance in either carbohydrate or fat consumption.

We find a significant positive association (1.5%) between the share of food derived from purchases and consumption of a balanced amount of dietary energy from proteins. This could indicate that relatively high protein-dense food items (e.g., animal source foods, legumes) are primarily sourced from markets, and this hypothesis is supported by the negative, though quite low, correlation between market access and balanced amount of dietary energy from proteins.

It is important to highlight the limitations of our study. Our data show that only 8.5% and 13.8% of the full sample and subsample of producers are VAC adopters, respectively (Tables 1A and 1B). This relatively small proportion of VAC producers might render the associations observed quite weak, given the low sample size. Furthermore, while through this study we are unable to find clear nutritional benefits due to the VAC integrated production system application, this is by no means a causal analysis from which we can infer direct impacts. Much of the efficacy (or lack thereof) of the VAC system can potentially be explained by the fact that households engaged in the different production practices are simply systematically different from one another, and they self-select themselves in each production system, as shown in Figure 1 through Figure 6. This finding is further supported by the positive associations of individual or combined components of the VAC production system with dietary outcomes.

Table 4: OLS Estimation

Independent Variables	Fruits and Vegetable Consumption	Fiber Consumption	Animal Protein Consumption	Dietary Energy Consumption
Household size	-9.775*** [-19.65]	-0.255*** [-17.80]	-2.218*** [-26.33]	-154.9*** [-23.44]
Female household head	0.0440 [0.02]	-0.0760 [-1.58]	0.510 [1.60]	-34.31 [-1.48]
Rural	-3.178 [-1.41]	0.0137 [0.23]	-0.0563 [-0.14]	85.51*** [2.89]
Most common educational qualification				
Primary	4.762** [2.51]	0.114** [2.00]	-0.269 [-0.77]	42.88 [1.56]
Lower Secondary	5.703*** [2.96]	0.110* [1.93]	0.174 [0.50]	70.83** [2.55]
Higher Secondary	0.236 [0.10]	-0.0396 [-0.63]	0.0272 [0.07]	131.8*** [3.94]
College & above	6.919* [1.94]	0.155* [1.73]	0.170 [0.29]	79.74 [1.64]
Household wealth index	12.23*** [11.22]	0.163*** [4.98]	3.343*** [17.69]	191.5*** [12.39]
Total production value (millions of *dong*)	0.0424 [1.47]	0.00292*** [3.71]	0.0331*** [6.38]	2.318*** [6.32]
Household produces				
Other crops (no VAC; with/without rice)	-4.133 [-0.97]	-0.143 [-1.26]	-1.530** [-2.07]	-114.6** [-1.97]
Livestock (with/without rice/other)	-1.790 [-0.57]	0.00784 [0.10]	-0.397 [-0.73]	-13.03 [-0.30]
Aquaculture (with/without rice/other)	3.290 [0.70]	-0.0343 [-0.28]	2.401*** [2.96]	19.21 [0.32]
F&V (with/without rice/other)	0.196 [0.06]	-0.0355 [-0.39]	-1.227** [-2.06]	-63.63 [-1.36]
Livestock and F&V (with/without rice/other)	0.900 [0.28]	0.166** [2.04]	-0.538 [-0.97]	-12.64 [-0.30]
Livestock and Aquaculture (with/without rice/other)	-5.231 [-1.41]	-0.0878 [-0.86]	0.778 [0.97]	31.50 [0.49]
Aquaculture and F&V (with/without rice/other)	8.428* [1.71]	0.352** [2.33]	-1.273 [-1.46]	-41.29 [-0.58]
VAC (with/without rice/other)	3.940 [1.14]	0.291*** [3.14]	0.141 [0.23]	12.34 [0.27]
Travel time to nearest market (minutes)	-0.211*** [-5.40]	-0.000215 [-0.20]	-0.0182*** [-2.77]	1.911*** [3.61]
Ratio of purchased food to total food value	1.485 [0.70]	-0.0169 [-0.29]	0.458 [1.48]	52.29** [2.11]
Biophysical (1995 - 2015)				
Mean Temperature (monthly averages, Celsius)	-4.355*** [-3.70]	-0.0709** [-2.28]	-0.912*** [-4.71]	-31.08** [-2.02]
C.V. Temperature	-91.38*** [-2.85]	-0.995 [-1.06]	-23.85*** [-3.95]	-1638.3*** [-3.50]
Mean Precipitation (monthly averages, mm)	0.0572 [1.60]	-0.00199** [-2.23]	0.0108* [1.90]	-0.206 [-0.52]
C.V. Precipitation	32.45** [2.18]	-1.318*** [-2.62]	2.823 [1.19]	-376.5* [-1.88]
Constant	212.3*** [6.59]	7.382*** [8.93]	50.38*** [9.17]	4121.4*** [9.24]
F-Statistic	30.36	22.24	44.31	28.48
F-Statistic P-value	8.12e-136	1.80e-99	2.54e-193	1.35e-127
R-square	0.169	0.107	0.213	0.146
Observations	6147	6147	6147	6147

t statistics presented in brackets.
* p < 0.1, ** p < 0.05, *** p < 0.01

Table 5: Logistic Estimation

Independent Variables	Balanced DEC: Carbohydrates	Balanced DEC: Fats	Balanced DEC: Proteins
Household size	-0.0485*** [-11.73]	-0.0381*** [-9.50]	-0.00575*** [-3.39]
Female household head	0.00352 [0.26]	0.0463*** [3.80]	0.00792 [1.15]
Rural	-0.0358** [-2.09]	-0.0425*** [-2.66]	-0.00226 [-0.21]
Most common educational qualification			
Primary	-0.0220 [-1.17]	-0.0308* [-1.76]	0.00224 [0.32]
Lower Secondary	-0.0379** [-2.07]	-0.0430** [-2.51]	0.00707 [0.99]
Higher Secondary	-0.00747 [-0.36]	-0.0238 [-1.28]	0.0219*** [2.75]
College & above	-0.00340 [-0.13]	-0.0290 [-1.18]	-0.00664 [-0.32]
Household wealth index	0.100*** [11.20]	0.0756*** [9.38]	0.0417*** [7.40]
Total production value (millions of *dong*)	0.000242 [1.14]	0.000174 [0.74]	0.000158 [0.98]
Production Categories			
Other crops (no VAC; with/without rice)	0.0143 [0.41]	0.0231 [0.67]	-0.00581 [-0.34]
Livestock (with/without rice/other)	-0.00788 [-0.33]	-0.00830 [-0.38]	0.00180 [0.14]
Aquaculture (fish or shrimp) (with/without rice/other)	0.0845* [1.94]	0.00433 [0.10]	0.0134 [0.95]
F&V (with/without rice/other)	0.0148 [0.54]	0.00861 [0.34]	0.00201 [0.15]
Livestock and F&V (with/without rice/other)	-0.0297 [-1.28]	-0.0248 [-1.18]	-0.00451 [-0.36]
Livestock and Aquaculture (with/without rice/other)	-0.0621* [-1.69]	-0.0596* [-1.67]	-0.0136 [-0.72]
Aquaculture and F&V (with/without rice/other)	-0.128*** [-3.57]	-0.0962*** [-2.76]	-0.0101 [-0.57]
VAC (with/without rice/other)	-0.0596** [-2.35]	-0.0634*** [-2.74]	0.00775 [0.57]
Travel time to nearest market (minutes)	-0.000358 [-1.11]	-0.000465 [-1.52]	-0.000351*** [-3.00]
Ratio of purchased food value to total food value	0.00980 [0.61]	0.00726 [0.47]	0.0146** [2.16]
Biophysical (1995 - 2015)			
Mean Temperature (monthly averages, Celsius)	-0.0306*** [-3.06]	-0.00187 [-0.20]	0.000222 [0.06]
C.V. Temperature	-0.369 [-1.16]	1.102*** [3.20]	-0.354** [-2.16]
Mean Precipitation (monthly averages, mm)	0.000565** [2.22]	0.000572** [2.40]	-0.0000740 [-0.61]
C.V. Precipitation	0.0648 [0.58]	-0.0554 [-0.54]	0.0170 [0.38]
Observations	6147	6147	6147

t statistics presented in brackets.
* p < 0.1, ** p < 0.05, *** p < 0.01

5. Conclusions

This study shows information on dietary patterns amongst households in Viet Nam, in relation to their production systems. Utilizing data from the VHLSS 2016, we take advantage of household food consumption data to construct dietary indicators beyond simple diversity count measures. Drawing from nutrition and public health literature, these indicators represent features of the diet that have been proven to be essential for healthy functioning of the human body. Our study is also aimed to provide quantitative evidence on the efficacy of Viet Nam's VAC model of integrated production. Recognizing the need to preserve soil quality and insulate farmer livelihoods from potential income and, consequently, consumption shortfalls, the government of Viet Nam has been encouraging farmers to adopt VAC sustainable intensification production systems. The objective of our paper is thus to examine existence and extent of any linkages between VAC production system and dietary outcomes.

We find some positive correlations between dietary indicators and certain specific components, of the VAC system, such as aquaculture and F&V production, although we do not observe consistent and strong associations to conclusively support a policy towards promoting the complete VAC production system with the purpose of improving nutritional outcomes. This result suggests that while VAC adoption might be effective in halting soil degradation and therefore improving environmental outcomes, its nutritional implications are uncertain. We find more conclusive evidence of the importance of travel time to market and, consequently, Vietnamese policy makers should prioritize connecting remote communities in order to ensure their market participation.

Nevertheless, our findings should be taken with caution given that VAC households comprise only 8.6% and 13.8% of households in the full sample and subsample of producers, respectively. Additionally, without being able to take advantage of an exogenous variation, or a controlled experiment, it is difficult to pinpoint the exact effect and causality mechanism of VAC production system on nutrition. According to our results, the various production categories are associated to different, systematic characteristics, which might be driving most of the correlations in our analysis. Endogeneity between production decisions and dietary outcomes or sample self-selection bias among households choosing to adopt the full VAC model cannot be ruled out. This suggests additional research to establish attribution between VAC production system and diets, potentially exploiting the panel structure of the Viet Nam Household Living Standards Survey.

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