Agriculture-Nutrition Linkages: Improving Food and Nutrition Security in the Potato-Based Highlands of Peru

By

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Abstract

The United Nations defines food security as people having at all times, physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. Due to the harsh environment, making agricultural production very difficult, Andean communities in the highlands of Peru rely heavily on potatoes as their main staple food. The lack of Iron (Fe) and Zinc (Zn) in these communities' diets result in above average child stunting rates and anemia. A low-cost, easy-to-use household food security assessment that comprehensively and validly distinguishes vulnerable households or individuals will greatly assist development organizations and governments attempting to fight hunger and malnutrition. This paper uses the US Household Food Security Survey Module and FAO's Women's Dietary Diversity Study to estimate probability of adequate iron intake using the full probability approach coupled with three possible iron concentrations from commonly consumed potato varieties. Calculations for the probability of inadequate intake show that if respondents were to shift their consumption of potatoes from low or medium to high iron concentration varieties, a 30% and 17% improvement in the probability of iron inadequacy would result among Andean women, respectively.

Keywords: Food security, nutritional security, hidden hunger, iron deficiency, Peru, Andes, adequate iron intake, full probability approach, US Household Food Security Survey Module, FAO Women's Dietary Diversity Study, potatoes.

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Introduction

The United Nations (1996) defines food security as "people having at all times, physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." In 2017, roughly 821 million people were considered food insecure, with the vast majority residing in developing countries (World Health Organization, 2018). In addition to this estimate, nearly 2 billion people suffer from at least one or more micronutrient deficiency (Graham et al., 2007). *Hidden hunger* is characterized by vitamin and mineral deficiencies due to a diet lacking nutrient-rich foods (Ruel, 2001). This may occur when an individual has a diet sufficient in calories but lacks adequate micronutrients. Symptoms for this phenomenon are not always obvious and most individuals may not be aware of it. However, the consequences may have lifelong implications on an individual's health, productivity, and mental abilities.

Due to the prevalence of hidden hunger and its dire consequences, it is imperative to combat this phenomenon in the most productive way possible. In Chapter 1 of this thesis I present a literature review of current food and nutritional assessments being used to measure food insecurity and hidden hunger throughout the world. In Chapter 2, I present a new approach to measuring these phenomena in the context of the Peruvian highlands. A low-cost, easy-to-use household food security assessment that comprehensively and validly distinguishes vulnerable households or individuals will greatly assist development organizations and governments attempting to fight hunger and malnutrition. The objective of this paper is to develop a standardized food and nutrition security assessment that can be administered for baseline and monitoring and evaluation purposes. In addition, this paper aims to address food-based strategies to reduce micronutrient deficiencies in the Peruvian Andes.

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1 Literature Review

1.1 Introduction

Over a quarter of the population in 2017 suffered from at least one or more micronutrient deficiency (World Health Organization, 2018). Iron and Vitamin A deficiencies are the most widespread micronutrient deficiencies in the world, disproportionately affecting children and women of childbearing age (Gillespie, 1998). These deficiencies result in anemia and child stunting, among many other impairments. Anemia in young children may impair growth, cognitive development and immunity. This can later affect school performance and adult working capacity. Anemia in childbearing mothers can lead to low birth weight or in severe cases, maternal death. A recent study by the Food and Agricultural Organization of the United Nations (UN FAO) (2015) found that anemia among women of reproductive age had risen between 2009-2014.

Child stunting is defined as impaired growth: being more than two standard deviations below the normal height for a certain age. It can negatively impact learning capacity and lead to lifelong chronic diseases. In 2015, 151 million children under five, or over 22 percent, were estimated to be stunted (World Health Organization, 2015). Furthermore, recent evidence suggests that food security and nutritional status is worsening in South America and most regions of Africa (World Health Organization, 2018). Determining those most vulnerable to food and nutritional security is an important step to monitoring and evaluation for project success and is just the first step towards developing policies and institutional interventions aimed at reducing hunger and malnutrition among women of childbearing age and children. The purpose of this literature review is to describe current approaches to determining food and nutritional security, and the challenges associated with them, and to provide justification for a new approach to assessing these issues in the developing world.

1.2 Food and Nutritional Security Assessments

Measuring food security has long been a topic of interest among development analysts and practitioners. The World Food Summit of 1996, comprised of representatives from 185 countries and the European Community, acknowledged three equally important core components, or domains (United Nations, 1996): availability, accessibility, and utilization.

Availability represents the physical existence of a sufficient quantity of food of appropriate quality; and is determined by domestic food production, domestic stocks, food imports, and/or food aid. Access captures a household's ability to purchase or acquire culturally acceptable food that is also nutritious. Utilization measures an individual's ability to effectively use the food and absorb the contained nutrients. Availability, access, and utilization are inherently hierarchical in nature: food availability is necessary but not sufficient for access, and access is necessary but not sufficient for utilization (Figure 1.1).

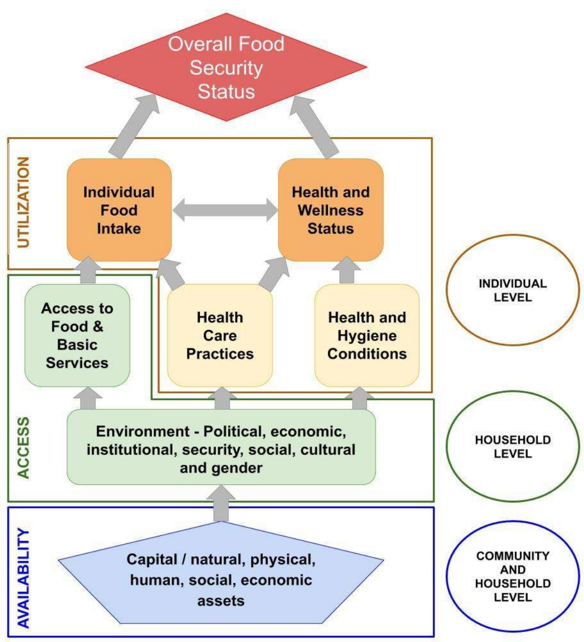

Figure 1.1. Conceptual framework for each domain of food security (World Food Programme, 2015). This figure simplifies the complexity of each independent, yet interrelated, domain while simultaneously defining key representative indicators.

Indicators for food security assessments are categorized as either fundamental or derived. Fundamental indicators presuppose no others, whereas derived measures assume a known empirical relationship (Campbell, 1928). Some examples of typically used derived measurements include income or assets while food consumption may be considered a fundamental measure. Derived measures are chosen because they are presumed to be highly correlated to food security but empirical evidence is needed to validate this. Additionally, correlates may differ in their strength of association to food security depending on the social and cultural context. For example, income may be of less importance to a household that grows most of their food. Exclusive reliance on derived measures may potentially overlook important causes and consequences of food security.

Food security assessments typically focus on availability, access, utilization, or any combination of these domains at a national, regional, household, and/or individual level. The content of these studies vary significantly from easy to collect and analyze measures to complex, time and resource intensive measures. The following types of assessments are presented to show the various domains at different scales that are currently being employed by development and aid organizations to determine food and nutritional security.

1.2.1 National Level Food Security Assessment

The World Food Programme has been prolific in developing national-level estimates of food security that are collectively known as vulnerability analysis and mapping (World Food Programme, 2009). These analyses are typically undertaken in developing countries using a multidimensional approach. One such study conducted by the World Food Programme (2015) adapted the conceptual framework from Figure 1.1 to include two additional domains: institutional capacity and stability. Institutional capacity is aimed at capturing regulation, financing, human resources, and social participation at a district and national level. Stability is the only exogenous domain aimed at identifying those vulnerable to natural disasters. This study is comprised of 17 derived indicators from publicly available census data (Table 1.1). The results were given on a district level (1,838 total) for all of Peru, thus providing a map of where populations are most vulnerable to food insecurity. The results from this study indicate that two of the top three most vulnerable departments in Peru: Huancavelica and Apurimac. These departments are where I focused this thesis research.

Table 1.1. Variables used for vulnerability to food security assessment conducted by the World Food Programme (2016). It follows the conceptual framework with two additional core domains: availability, access, utilization, institutional capacities, and stability. All indicators are drawn from public data.

Level	**Indicator**
Availability	Concentration index of Herfindahl - H
	Ratio of rainfed to irrigated agricultural land
	Ratio of land cultivated for household consumption
Access	Per capita family income index gap
	Ratio of economically active occupied agricultural population
	Ratio of the population in housing with dirt floors
	Ratio of population in housing without electricity
	Ratio of the Population in Development Process and Social Inclusion
Utilization	Women's illiteracy rate
	Ratio of the men of households who haven't completed primary school
	Ratio of housing without safe public water system
	Ratio of housing without sanitary sewer system
	Ratio of the population of households that cook with firewood
Institutional Capacities	Gap of the local government management index
	State density index gap
Stability	Recurrence of natural disasters
	Affected population of natural disaster

This assessment provides a national-level estimate of food security that can inform national monitoring and early warning systems. While this study gives a district level scale of vulnerability in Peru, many studies have found that variability of food security can vary greatly even within a household due to biases in gender and other social constructs (e.g. Cogill & Kennedy, 1987; Haddad, Nishida, Peña, Quisumbing, & Slack, 1996; Maluccio & Quisumbing, 2000). Therefore, intra-household assessments are needed to better understand the consequences and determinants of this phenomenon in relation to women of childbearing age and children.

1.2.2 Household Food Access Measures

This popular assessment aims to measure the access component of food security. Questions about food acquisition and food consumption are used as a metric to measure a household's physical and economic access to food. What results is a more vivid understanding of food security than just relying on nationally aggregated data.

The household consumption and expenditure surveys (HCESs) use indicators such as monetary expenditure, education, housing type and quality, assets, health-seeking behavior, and income to measure poverty, consumer price indices, household socioeconomic status, and patterns of food consumption (Fiedler, Carletto, & Dupriez, 2012). This assessment operates under the assumption that food acquisition results in food consumption. However, recent research suggests that acquisition-consumption equality may be true only for population-level estimates of food consumption (National Research Council, 2012; Smith & Subandoro, 2007). This is because estimates can result in dramatically different results depending on the time of the year, especially in agriculture dependent communities. Harvest losses and storage failures can result in severe food shortages, while harvesting time is perhaps the most secure of the year. Research also shows that differences in earnings between husband and wife translate to differences in consumption allocation within the household (Lise & Seitz, 2011). Food acquired may also be wasted, gifted, or fed to animals; thus over- or under-estimation of food intakes is a consequence of only relying on food expenditure data (Bouis, 1994).

HCESs are a popular choice for development organizations because they are low cost and less time-consuming than other dietary intake assessments or observed-weighed food records that measure food consumption. These assessments are widely used around the world, but are only estimates of food acquisition and not physical or economic access to food. Perhaps more importantly, HCES data do not account for individual consumption, therefore identifying vulnerability among certain groups such as infants, young children, pregnant women and lactating women is not in the scope of this assessment. Other methods that accurately assess individual dietary intake are needed for this purpose.

1.2.3 Dietary Diversity

Another derived measure widely used to estimate food security is the dietary diversity proxy. Numerous studies demonstrate the positive association between dietary diversity and both nutrient quality of diets and child anthropometry (e.g. Hatløy, Torheim, & Oshaug, 1998; Kant, 1996; Onyango, Koski, & Tucker, 1998; Rose, Meershoek, Ismael, & McEwan, 2002; Savy, Martin-Prével, Sawadogo, Kameli, & Delpeuch, 2005). More recently, dietary diversity has been used as an indicator for food security (Ruel, 2003). It has also been shown to be associated with various socioeconomic measures that are commonly considered proxies for food security such as household assets, education, income and per capita daily caloric availability (Hatløy, Hallund, & Diarra, 2000; Anzid et al., 2009; Rashid, Smith, & Rahman, 2006; Hoddinott & Yohannes, 2002).

Dietary diversity indicators such as the household dietary diversity score (HDDS) developed by FANTA and the Food Consumption Score (FCS) developed by WFP differ in recall period, the number and definition of food groups, the weighting of food groups, and assessment of cutoff points for defining insecurity and the appropriateness culturally of the groups (Swindale & Bilinsky, 2006; World Food Programme, 2007). However, both indicators have proven to perform similarly in diverse contexts (Kennedy et al., 2010). A score is calculated from the responses by summing the number of food groups consumed. Issues may arise by using this standardized scoring system. For example, in regions where fruits and vegetables are not easily accessible, consumption of these food groups may indicate food security, but this scoring system does not discern this important distinction. Adaptation of the main food groups and cutoff points for determining insecurity is required to fit the cultural context and may require additional resources. The benefits of dietary diversity are minimal data collection and empirical evidence that suggests its strong correlation to food security (Hatløy, Hallund, & Diarra, 2000; Hoddinott & Yohannes, 2002; Rashid, Smith, & Rahman, 2006; Anzid et al., 2009).

1.2.4 Experience-Based Measures

Rather than using indicators like the above, experience-based measures utilize simple questionnaires to measure a household or an individual's behavior and lived experiences around food security (Barrett, 2001). This type of measure differs from the previous ones in that it attempts to cut across all three domains (availability, access, utilization) to measure food security directly. Questions regarding a household's or individual's subjective experience are carefully chosen to reflect various dimensions of food security. Results inform institutional interventions and assist with monitoring and evaluation.

One such survey, the Household Food Security Survey Module (US HFSSM) is an 18-question survey module that categorized a household's food security as either high, moderate, low or very low. Several studies show that an adapted version of this assessment issued in developing countries was associated with total daily per capita food expenditures, net income per adult, total assets, and dietary diversity (Coates, Webb, & Houser, 2003; Frongillo & Nanama, 2006; Melgar-Quinonez et al., 2006; Pérez-Escamilla, 2004). However, other literature suggests that universal cutoffs for defining the severity of food insecurity was not possible (Coates, Frongillo, Rogers, Webb, Wilde, & Houser, 2006). Therefore, context-specific cutoffs should be used to properly determine insecurity among households or individuals.

All assessments have inherent strengths and limitations, therefore, the trade-offs must be acknowledged by those who use them. The choice of using derived vs. fundamental indicators depends on many factors and both can be used to accurately capture food security if used in the correct culture and context. Implementation of these assessments are usually limited to the amount of time and resources available for the project.

In order to capture all the important elements of individual food and nutritional security, multiple assessments and indicators should be combined to cross validate results and provide a richer account of security among differing domains (Jones, Ngure, Pelto, & Young, 2013). Since each project is unique in its project budget and scope, the assessments should be tailored to fit the project goals and outcomes.

1.3 Nutritional Interventions

Many international nutrition interventions have primarily focused on supplementation and fortification programs (Ruel, 2003). One example is iron supplementation. Previous research concludes that iron supplementation during pregnancy prevents maternal iron deficiency and anemia while women who are most anemic benefit the most (Pena-Rosas & Viteri, 2009). However, many iron supplementation programs are generally poorly implemented and as a result have little global impact (Stoltzfus, Mullany, & Black, 2005). Perhaps the greatest factors for this include geographic distance, low motivation and poor interpersonal skills of health staff, and low compliance rates among women due to unwanted side effects (Schultink et al., 1993). A study conducted among 985 pregnant women in Peru concluded that patterns in compliance have improved in recent years with compliance falling within the average range of 70-95% (Aguayo et al, 2005; Seck & Jackson 2007; Lutsey et al., 2008; Zavaleta, Caulfield, Figueroa, & Chen, 2014). The healthcare providers in this Peruvian study reinforced consumption of the supplements through weekly home visits and monthly check ups in the health care facility. Therefore, such efforts may be attributed to the high compliance rate but data could not be directly linked to this result. Another study also highlighted the integral role that health personnel had in influencing consumption of micronutrient fortified foods in Peru (Creed-Kanashiro, Bartolini, Abad, & Arevalo, 2016). Both studies conclude that supplementation and fortification can be an effective intervention strategy when they are readily available and the healthcare system is set up to strongly promote consumption.

The largest social and nutritional assistance program in Peru, *Vaso de Leche* (Glass of Milk), was introduced in Lima, the national capital, in 1984 and expanded nationally in 1998 (Stifel & Alderman, 2006). The program aims to provide a glass of milk daily to children under the age of 7 and pregnant or lactating women. Secondary beneficiaries include children aged 7-13, the elderly, and individuals with tuberculosis (Copestake, 2008). Stifel and Alderman (2006) evaluated the impact of this program on child nutritional outcomes. They found that the program was well targeted to poor and malnourished children but ultimately failed to improve their nutritional status. Considering the program's costly annual budget of $97 million in 2001 and its insufficiency to reduce child malnutrition, alternative programs could be less costly and potentially more efficient.

1.4 Conclusion

Food and nutritional security are immensely important issues facing millions of people throughout the world and in Peru. Current estimates and future projections are important drivers for government policy through Feed the Future Initiative, and significantly impact aid decisions through the World Bank's Global Agriculture and Food Security Program. Since malnourished populations are less economically productive, food security is essential for a thriving economy (Jones et al., 2013). Retreating from complete dependence on derived measures to refocusing this multidimensional phenomenon using both fundamental and derived measures will provide a richer, more accurate depiction of food security. A low-cost, easy-to-use household food security assessment that comprehensively and validly distinguishes vulnerable households or individuals will greatly assist development organizations and governments attempting to fight hunger and malnutrition. The objective of this research is to develop a standardized food and nutrition security assessment that can be administered for baseline and monitoring and evaluation purposes. In addition, this work aims to address food-based strategies to reduce micronutrient deficiencies in the Peruvian Andes.

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2 Food and Nutritional Security Assessment and Analysis

2.1 Introduction

The International Potato Center (CIP) is an agricultural research facility focused on scientific research and project implementation for potatoes, sweet potatoes, and other root and tuber crops. It is one of 15 specialized research centers of the Consultative Group on International Agricultural Research (CGIAR). The data for this analysis come from a much larger project carried out by CIP from 2011-2015, called the Innovation for Food Security and Sovereignty in the Andes (IssAndes). The project spanned the highland regions of Peru, Bolivia, Ecuador, and Colombia, and was funded by the European Union through the International Fund for Agricultural Development (IFAD). CIP worked alongside other research and development institutions to implement this project, in particular, CARE Peru, CAPAC Peru, PRISMA, and ADERS Peru. In addition, CIP collaborated with the Institute for Nutrition Research (IIN) to implement this project. The IssAndes project team identified which native potato varieties were higher in zinc and iron, re-introduced them to vulnerable communities, and promoted them through educational programs. The project also held workshops to provide practical advice to improve the communities' daily diets while also informing them of the nutritional advantages of native potatoes. The overall goal was to build the capacity of potato producing households to increase income and employment, improve diet, and reduce malnutrition (Ordinola, Fonseca, Vela, & Devaux, 2014).

Baseline data were collected from 22 communities in the highlands of Peru. These same communities participated in the projects' development activities. This paper only uses the baseline data collected from Peruvian households. Two lengthy surveys were administered to the households. A production baseline study, administered to the head of household, gathered information on the household's agricultural production systems, assets, and other socioeconomic variables. A nutrition survey, administered to the mother of the household, included a variety of smaller surveys, such as the US Household Food Security Survey Module (HFSSM) and FAO Women's Dietary Diversity Score (WDDS). Survey questions were specific to the mother, such as education, age, and nutritional knowledge. Both surveys are in Appendix A and B, respectively. The analysis in this paper seeks to determine the status of food and nutritional security of these communities so future projects can tailor the development activities to better suit each communities' needs. IssAndes also never conducted any monitoring or evaluation due to limited project funds. The analysis present here can also be used for monitoring and evaluation due to its ease of replication and low-cost administration and analysis. Using the baseline data as a standardized model to analyze community survey data can help future development projects assess communities' needs and tailor the limited time and resources to effectively target populations that are most vulnerable to food and nutritional insecurity.

2.2 Study Site

The Andes mountain range in Peru reaches as high as 7,000 meters and is in the middle of the country with little access to major cities or hospitals. The high elevation and sloping land make agricultural production very restrictive in this region. These communities rely heavily on potatoes as their main staple food to meet minimum caloric intake (Figure 2.1). Anemia is a chronic problem in the region occurring in 43% of children under the age of 5, and 21% of women of childbearing age (Ordinola, 2013). The lack of iron (Fe) and zinc (Zn) in these communities' diets yield additional problems such as above average child stunting rates and mothers that are unable to provide nutritious breast milk to their young (Lechtig, Cornale, Ugaz, & Arias, 2009).

Figure 2.1. Typical market in the Andean town of Huaraz. Potatoes are a staple food and are abundant in all Andean markets. Photo by Zainab Husain.

To determine the study site, IssAndes grouped poverty and potato production data into three classes: low, medium and high. The potato production data came from the National Agricultural Census (Ministry of Agriculture, 2008) and the poverty rates came from Escobal & Ponce (2008). Both variables were combined and mapped to show the spatial distribution of vulnerability in the country (Figure 2.2).

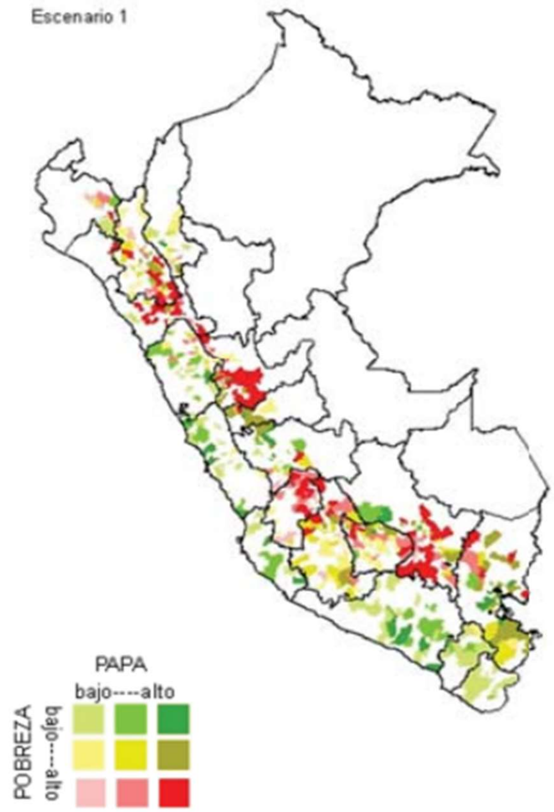

Figure 2.2. Levels of poverty and potato production in Peru. Regions in red indicate where the presence of potato production and poverty is high. (Ordinola et al., 2014)

IssAndes determined that the departments of Apurímac and Huancavelica were the target regions for intervention. The project concentrated their efforts specifically on the communities located in the regions shown in red (Figure 2.3). A further breakdown of the characteristics of poverty in these two departments in shown in Appendix C. The project included participants from eight districts in Huancavelica and two districts in Apurímac. Between the ten districts, 22 different communities were studied. All communities were in rural regions of the highlands, some with poor roads connecting to major cities.

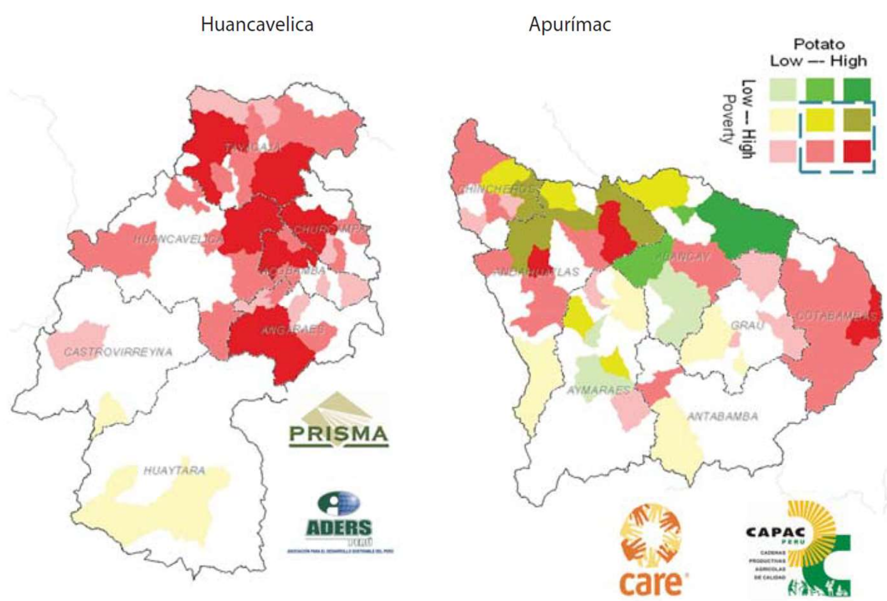

Figure 2.3. Poverty and potato production by department (Ordinola et al., 2014). Dark red indicates high poverty and high potato production while light green indicates low poverty and low potato production.

2.3 Participants

The target sample group was small agricultural producers within the intervention area. All households had at least one child under the age of three. Based on information gathered from the baseline report, most families manage less than one hectare of farmland and produce under rainfed conditions. Potato is the most predominant crop, followed by corn, barley and beans. Livestock is also present in most households. Most household expenditures are used to purchase food (on average 55% of total expenditure). Prevalence of chronic malnutrition is especially high among children between 12 and 24 months (58.3% in Huancavelica and 42.3% in Apurímac). The most consumed foods by children less than two years old are cereals, followed by roots and tubers, and *caldos* (typical Andean soup). Chicken or beef *caldos* are very popular in the region. However, the amount of potatoes and broth in comparison to meat and vegetables is very large. Animal products are not commonly consumed by children. Consumption of critical nutrients, such as folates, calcium, iron, and zinc, is very low. In Huancavelica, 81% of children do not receive the minimum requirements of iron and zinc, as compared to 62% in Apurímac (Ordinola et al., 2014).

For this study, a total of 266 women responded to the production and nutrition survey. All characteristics such as socio-economic status, household size, and agricultural productivity varied greatly (Table 2.1)

Table 2.1. Key social characteristics of 266 women respondents to both surveys.

Variable	Number	Percentage	Variable	Number	Percentage
Age of Study Respondents			Participation in Community Organizations		
18-28	128	46	Vaso de Leche	241	87
29-39	108	39	Promotores de Salud	8	3
45-58	41	15	Comodor Popular	49	18
Family Size			Club de Madre	33	12
≤4	121	44	Potato Production (kg)		
5-7	120	43	≤ 500	61	24
≥8	16	6	501-2,000	104	40
Education			2,001-10,000	71	28
Primary Complete	57	21	> 10,000	22	9
Primary Incomplete	88	32	Livestock Rearing		
Secondary Complete	68	25	≤ 2	74	28
Secondary Incomplete	34	12	3-4	105	40
No Education	30	11	>4	86	32
Housing					
Own	208	75			
Other (Rented, Parents)	69	25			

2.4 Data Collection and Analysis

Much of the highlands are populated by indigenous communities. Surveys from the broader IssAndes project were administered by local community members who spoke both Quechua, the local language, and Spanish (Figure 2.4). When these local community members were trained beforehand on how to administer the survey and answer any follow up questions. Once surveys were completed, all responses were translated to Spanish by IssAndes personnel.

Figure 2.4. IssAndes survey being administered in Huancavelica by trained community members (Ordinola et al., 2014)

2.5 Materials and Methods

To determine food and nutritional security, two assessments were selected from the IssAndes nutrition baseline survey: US Household Food Security Survey Module and Women's Dietary Diversity Score. These studies were chosen due to their ease of replication and low-cost administration and analysis. Using the Women's Dietary Diversity Score, an estimate of each respondents' total iron intake was calculated by averaging each food group's iron content and adding them together. Then the probability of iron inadequacy among the sample size was estimated using the full probability approach. Because iron requirements in women of childbearing age are positively skewed due to high menstrual losses, the probability approach is the most comprehensive way of determining inadequacy (Beaton, 1972; Institute of Medicine, 2001).

2.5.1 US Household Food Security Survey Module

The original Household Food Security Survey Module is an 18-item survey with questions pertaining to the respondent and children in the household. In this study, the eight questions pertained to the children were removed. The remaining nine questions were specific to the respondents' experience with food security. The questions were modified and adapted to include only those questions that were culturally appropriate to the surveyee, which in this case was the childbearing mother. The 9 questions that were administered in IssAndes can be seen in Appendix D. One major change to the adapted version was the simplification of the response options. Rather than having multiple levels of severity as responses, the responses were simplified to either yes or no.

Responses were coded as 1 for "Yes" and 0 for "No". For those that responded either "a" or "b" to question 1 and "No" to questions 2-4 were given an overall score of 0 regardless of their answers to the remaining questions. Item responses were summed for questions 2-9 to create the overall food security score (FinSS). The food security score ranges from 0-8, 0 being the most food secure and 8 being very food insecure.

While this method successfully identifies whether households are receiving an adequate quantity of food, it does not recognize the quality of food they are eating. This distinction is important, especially in the Andean highlands, because most households may not be immediately experiencing hunger but are severely micronutrient deficient. Therefore, a second measure was used in the data analysis to determine nutritional status among women of childbearing age.

2.5.2 Women's Dietary Diversity Study

The FAO Women's Dietary Diversity Study is a measure of micronutrient intake specifically designed for women of childbearing age. The questionnaire was filled out by the respondent for all foods eaten in the past 24 hours (Appendix E). With the help of local knowledge, this survey was adapted to include local foods and remove those that are not common in the region.

A women's dietary diversity score was calculated for each respondent by aggregating the food groups into 9 main food groups (Table 2.2).

Table 2.2. FAO main food groups used to calculate women's dietary diversity score after aggregating all food groups.

Aggregate	Food Group
A, B	Starchy Staples
D	Pulses
E	Leafy Greens
C, F	Vitamin A Fruits and Vegetables
G	Other Fruits
H	Organ Meats
I, J	Meat and Fish
K	Eggs
L	Dairy

The 'aggregate' column indicates which food groups, corresponding to Appendix E, were aggregated together. The main food groups chosen for this study were an adaption of the FAO and FHI 360 (2016) and Kennedy, Ballard, and Dop (2011) versions of the Women's Dietary Diversity Score. This adaption aims to account for cultural differences in food preferences within the project region. The main difference is the removal of nuts and seeds as a main food group since these food items are not readily accessible or available to Andean communities. A comprehensive list of specific food items comprising each of the nine food groups is provided in

Appendix E. A score from 0-9 is given for each respondent, representing their overall dietary diversity.

2.5.3 Estimating Available Iron

Nutrient intake calculated from food composition tables represents the maximum amount of the nutrient present in the food. However, the amount actually absorbed and used by the body is much lower and varies greatly between individuals. The amount of iron absorbed and utilized by the individual, also known as bioavailability, depends on both the iron status in the body and the content of their diet (Hurrell, 2003; WHO & FAO, 2004). FAO and WHO (2002) estimate that the bioavailability of diets primarily based off plant based foods (such as cereals, roots and/or tubers) to be either 5 or 10 percent and meat based diets at 15 percent.

Using the dietary diversity survey responses, iron content was gathered for the most commonly eaten food items in each food group using the USDA Food Composition Databases (2018). Portion sizes were assumed to be one regular portion as per the USDA standards. These values accounted for nutrient losses during the cooking process. For each food group indicated on the Women's Dietary Diversity Score, the iron content was gathered for each of the popular food items, and the average is calculated in the far right column (Table 2.3). The daily iron content per day of each respondent was calculated by summing the average iron content for each food group they indicated eating on the Women's Dietary Diversity Score. Another food group, labeled 'Starches' was added because every respondent indicated eating them in the recall period. Of all the respondents, 212 said they had eaten at least one iron enriched starch (either rice, pasta or bread). For those that said they ate an enriched starch, the enriched average iron content was used instead of the starch iron content. The average iron content used for the analysis are shown on the following page in Table 2.3.

Table 2.3. Average iron content used for each food group (USDA Food Composition Databases, 2018))

Food Group	Food Item	Food Intake, g (Serving Size)	Iron Content, mg	Average Iron Content, mg
		Heme Iron		
Organ Meat	Liver	85	10.95	10.95
Flesh Meats	Beef, chuck	84	2.70	
	Chicken, dark meat	110	1.40	1.97
	Turkey, breast	146	1.80	
	Trout, fillet	62	1.2	1.25
Fish	Fish, tuna canned	85	1.3	
		Non-Heme Iron		
Leafy Green Veggies	Spinach	100	3.60	
	Broccoli	156	1.05	2.33
	Chard	100	2.30	
Pulses	Garbanzo	164	4.74	
	Lima beans	179	6.60	
	Lentils	198	6.59	5.13
	Black beans	172	3.61	
	Green split peas	100	4.11	
Vitamin A Fruits	Papaya	145	0.25	0.26
	Mango	165	0.26	
	Pumpkin	245	1.40	
Vitamin A Veggies	Carrots	85	0.80	1.10
	Sweet potato	151	1.10	
Other Fruits or	Banana	136	0.40	
Veggies	Onion	87	0.27	0.47
	Tomato	121	0.73	
Starches	Rice	186	2.70	
	Bread	56	1.80	
	Noodles	242	1.79	2.86
	Amaranth	246	5.20	
	Quinoa	246	2.80	
Egg	Egg, Cooked	50	0.59	0.59
Enriched Foods	Pasta	250	8.00	4.72
	Bread	56	1.44	

To determine nutrient quantity of local potato varieties, the range and mean of iron concentration on a fresh weight basis (2.2-8.0 mg/kg-1) from 12 predominant potato varieties in Huancavelica were used (Burgos et al., 2007). A sensitivity analysis of iron concentration in potatoes was conducted using the iron concentration multiplied by the respondents' quantity potato consumption. A list of the dry weight iron concentrations of the 12 predominant potato varieties are shown in Table 2.4. The five most commonly produced potato varieties by households of survey respondents were huayro, peruanita, unica, yungay, as well as papa blanca and papa nativa. Papa blanca and nativa are general terms used to describe a broad group of potato varieties. Given this diversity, an average of the 12 predominant varieties in Huancavelica captures the various varieties consumed within households.

Table 2.4. Iron Concentration (mg kg-1 Dry Weight) of raw and cooked tubers of 12 native potato varieties in Huancavelica (Burgos et al., 2007)

Variety	Raw	Cooked
Ajo Suytu	18.4	16.4
Allga Palta	9.4	10.4
Ayrampo	19.8	16.7
Gorimarquina	18.5	19.1
Pasna	24.5	22.3
Peruanita	13.9	14.5
Poccya	21.0	22.4
PucalHuayro	19.1	20.4
RetipaSisan	18.7	18.0
Runtus	25.2	22.4
Sirina	18.5	18.7
Sortiguillas	10.4	9.8

2.5.4 Estimating Probability of Adequate Intake

Most nutrients' estimated average requirement follows a normal distribution but iron requirements in women of childbearing age are positively skewed due to high menstrual losses (Beaton, 1972; Institute of Medicine, 2001). The full probability approach is the most comprehensive way to estimate the prevalence of inadequate intake for a population group. This approach requires knowing the distribution of observed iron intakes and the probability of inadequate intakes (mg/d) (Table 2.5). I modified the table to represent 10% bioavailability, per FAO and WHO (2002) recommendations. To calculate the probability of inadequate intake for the population, first, the percent of individuals within each iron intake range was determined. The percentage was then multiplied by the probability of inadequacy. The sum of percentages indicates the total percentage of individuals in the population who are at risk of inadequate iron intake (Gibson & Ferguson, 1999).

Table 2.5. Probability of inadequate iron intake for the population (mg/day) (Modified from Institute of Medicine, 2001)

Probability of Inadequacy	**Iron Intake* mg**
1	< 7.5
0.96	7.5-8.4
0.93	8.4-9.4
0.85	9.4-10.7
0.75	10.7-11.8
0.65	11.8-12.9
0.55	12.9-13.9
0.45	13.9-15.1
0.35	15.1-16.6
0.25	16.6-18.7
0.15	18.7-22.5
0.08	22.5-26.7
0.04	26.7-31.5
0	> 31.5

*Intake based off 10% bioavailability (FAO & WHO, 2002)

2.5.5 Statistical Analysis

Statistical analysis were performed using R version 1.1.463 (R Core team). Iron requirements were calculated separately by constructing a matrix of the probability of inadequate intake as per Institute of Medicine (2001) recommendations. Pearson’s correlation was run to verify the linear association for the food security score and Women's Dietary Diversity Score. Rather than categorizing the food security score into different levels of severity, the raw score was used in all regressions as a continuous variable. Linear regression models were used to assess whether there were statistically significant ($P < 0.05$) associations between the food security score and Women's Dietary Diversity Score with other socioeconomic variables. Backward elimination of variables was used with stepwise regression to determine the model's best fit. A sensitivity analysis was performed to determine the range of iron intake using various levels of iron content in local potato varieties. The probability of inadequate iron intake of the population was calculated using the numbers generated from the sensitivity analysis.

2.6 Results

2.6.1 US Household Food Security Survey Module - Food Security Score

In this study, the mean food security score was 3.18 with respondents' score ranging from 0 (very food secure) to 8 (very food insecure). Of the 266 respondents, the mode was 0, indicating that those respondents answered no to all the questions in the US Household Food Security Survey Module (Figure 2.5). Very few respondents were determined to have very low food security (a total of 22 respondents scored 7 and 8).

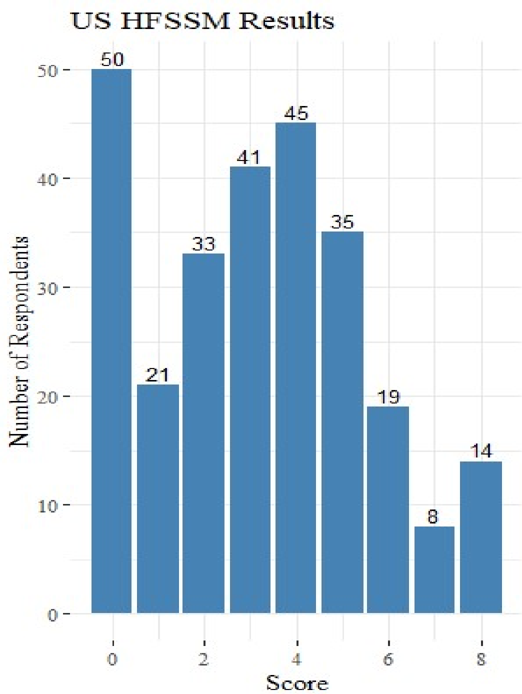

Figure 2.5. Food security scores based on the US Household Food Security Survey Module for 266 respondents in the central Peruvian Andes.

2.6.2 Women's Dietary Diversity Score

The mean Women's Dietary Diversity Score was 4.62 and the score ranged from two to eight. A breakdown of the percentage of each main food group consumed is provided in Table 2.6. Every respondent consumed a starchy staple in the recall period and the least consumed food group was dark green leafy vegetables. Of the ten respondents who only ate two food groups, they either consumed milk, meat, eggs or legumes with a starchy staple. Two respondents consumed eight of the nine food groups; dark leafy green vegetables being the only missing group for both. Only 25 women indicated having eaten organ meats in the recall period and of those 25, 19 had also eaten either meat or fish.

Disaggregating the meat and fish food group into its components - fish and flesh meats - shows that consumption of fish is rather low, while that of flesh meats is relatively high (Figure

2.6). The flesh meat category encompasses food items such as beef, pork, chicken, turkey, guinea pig, alpaca, or vizcacha in the fresh or dry form, but excludes organ meat.

Table 2.6. Summary of food group intake by women of childbearing age (N=266)

Food Group	Number	Consumption (%)
Starchy staples	266	100
Dark green leafy vegetables	9	3.4
Vitamin A fruits and vegetables	185	69.5
Other fruits and vegetables	149	56.0
Organ meats	24	9.0
Meat and fish	186	69.9
Eggs	108	40.6
Pulses (beans, peas, lentils)	119	44.7
Dairy	182	68.4

Disaggregating the meat and fish food group into its components - fish and flesh meats - shows that consumption of fish is rather low, while that of flesh meat is relatively high (Figure 2.6). The flesh meat category encompasses food items such as beef, pork, chicken, turkey, guinea pig, alpaca, or vizcacha in the fresh or dry form.

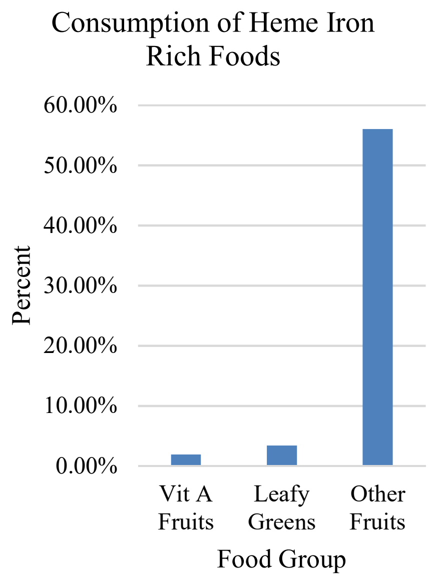

Figure 2.6. Consumption of three food groups rich in heme iron (organ meats, fish, flesh meat) consumed by respondents in the last 24 hours prior to the interview. N=266

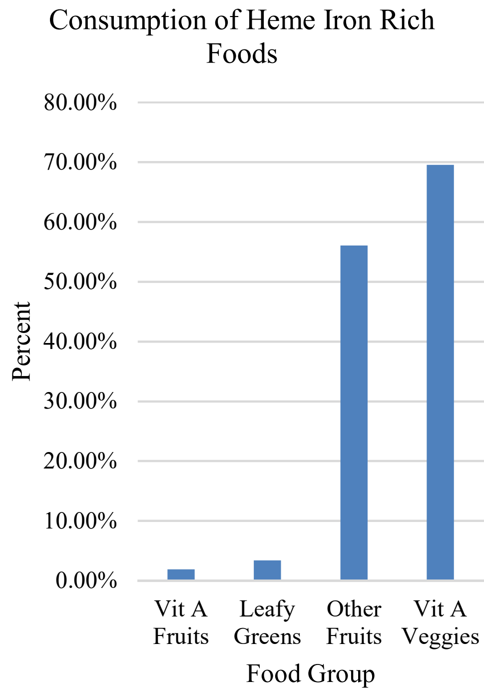

Figure 2.7. Consumption of four non-heme iron food groups (vitamin A fruits, leafy greens, other fruits, vitamin A vegetables) consumed by respondents in the last 24 hours prior to the interview. N=266

Disaggregating the fruit and vegetable food groups into its components shows a more in-depth look at consumption (Figure 2.7). Vitamin A-rich fruits and leafy green consumption was very low among the sample size, while more than half of the respondents indicated eating vitamin A vegetables and another type of fruit or vegetable.

All of the women consumed potatoes in the recall period. The average quantity of potatoes consumed by the respondents was 915 grams. The amount consumed by the respondents varied greatly (Figure 2.8). The smallest quantity of potatoes consumed was 156 grams while the largest was 2,729 grams. The average number of potato varieties produced by each respondent's household was 2, with some families producing only 1 variety, and others producing up to 9. The most common native potato varieties in the region are listed in Table 2.4.

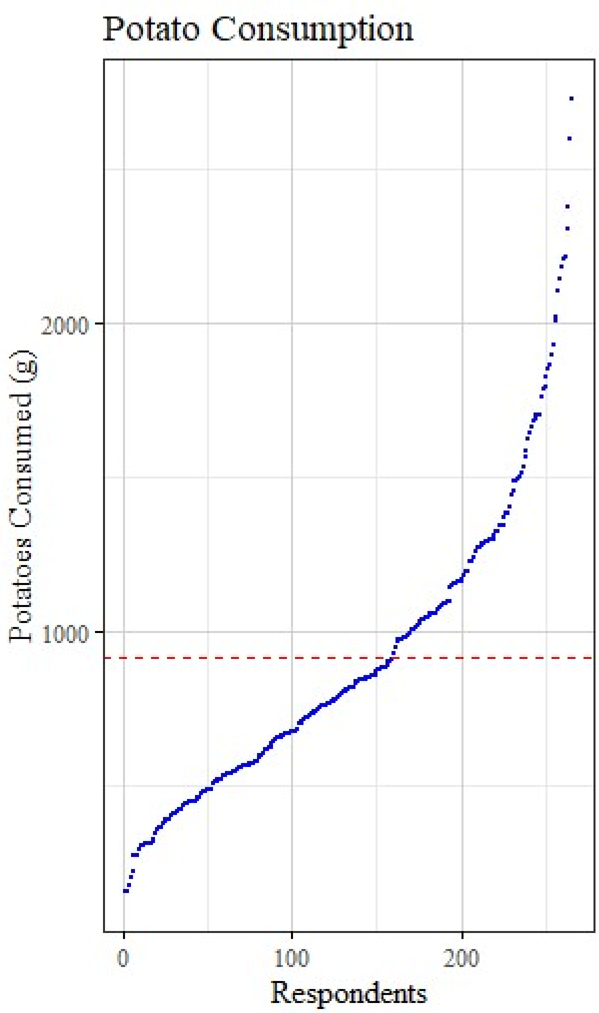

Figure 2.8. Incremental plot of respondents vs amount of potatoes consumed (g) in the last 24 hours. Data from 266 respondents in the IssAndes survey. The red dashed line indicates average consumption (915 grams)

2.6.3 Bivariate Analysis

A Pearson correlation was conducted between the food security score and Women's Dietary Diversity Score and the correlation coefficient was -0.20, indicating a small negative correlation (Figure 2.9). Although counter intuitive, the small negative correlation indicates that as food security increases (lower score means higher food security), diversity increases as well. There was strong support that the correlation coefficient was different from zero (p=0.0014). The R script with the full correlation results is in Appendix G.

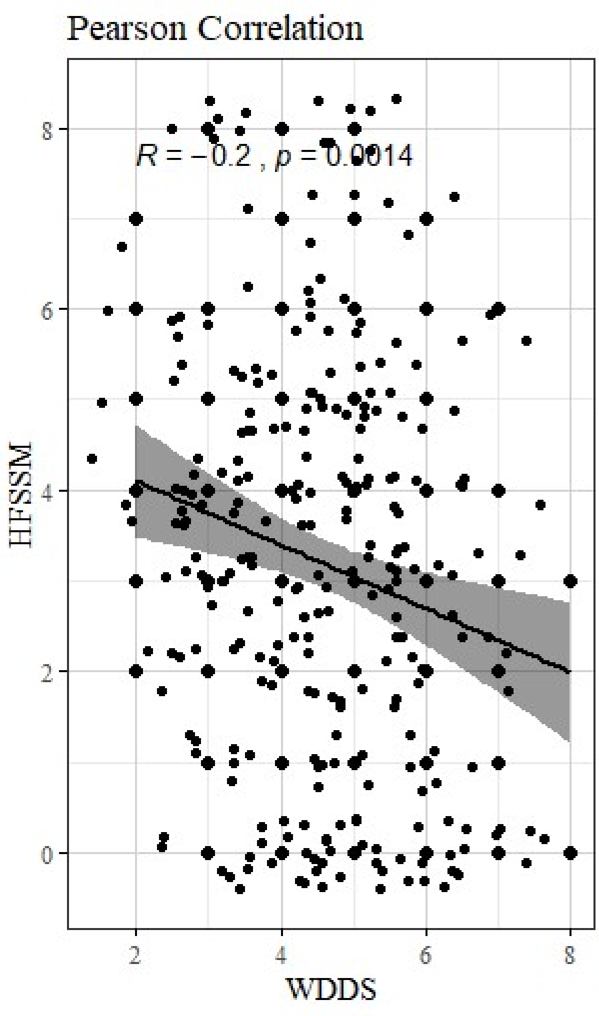

Figure 2.9. Pearson Correlation between the US Household Food Security Survey Module (HFSSM) and Women's Dietary Diversity Score (WDDS); HFSSM = 4.11 – 0.001WDDS

2.6.4 *Multivariate Analysis*

A multivariate regression was conducted with the food security score as the independent variable and all the food groups from the Women's Dietary Diversity Score except for starchy staple (Table 2.7). The full R code is in Appendix G.

Table 2.7. Multivariate regression of food groups by the food security score

Food Group	**Coefficient**	**P-value**
Legumes	-0.59	0.039
Dark Leafy Green Vegetables	-0.4	0.600
Eggs	-0.12	0.683
Other Fruits	-0.38	0.190
Vitamin A Fruits and Vegetables	-0.1	0.736
Milk	-0.02	0.950
Organ Meats	-0.5	0.303
Meat	-0.39	0.214

The signs of all variables were negative, indicating more consumption of the food group resulted in higher food security. Legumes proved to be the only food group that was statistically significant to the food security score. Legumes also had the largest regression coefficient to food security, while organ meats was the second strongest. Milk was the least significant food group to obtaining high food security. The model R^2 value was 0.08.

Two more multivariate regressions were conducted using the food security score and Women's Dietary Diversity Score as the independent variable and socioeconomic information as the dependent variables (Table 2.8 and 2.9, respectively). Some variables used in the initial regression that were ultimately removed after the backward stepwise regression were total family members, number of livestock owned, and diversity of potato varieties. Two variables were significant in both regressions: amount of potato consumed and crop diversity. The only variable with a positive coefficient was crop diversity, indicating higher crop diversity led to high food insecurity. The R code used for both analyses can be found in Appendix H.

Table 2.8. Regression model of the relation between socioeconomic variables and the food security score

Variable	Coefficient	P-value
Housing owner	-0.53	0.083.
Amount of potato consumed (g)	-0.001	0.000
Crop diversity	0.14	0.101
Education of mother	-0.01	0.008
Education of father	-0.01	0.008
Water access	-0.01	0.116

Respondents with a food security score of 0 had high food security while those with an 8 had very low food security. Variables with a negative regression coefficient indicate a higher food security with a unit increase of that variable. Binary variables such as housing and water access were coded as 1 for affirmative and 0 for no. The R^2 for this model was 0.13.

Table 2.9. Multiple Regression of socioeconomic variables by Women's Dietary Diversity Score

Variable	Coefficient	P-value
Grams of Potatoes Consumed	0.00	0.017
Crop Diversity	-0.10	0.046
Age of Father	0.02	0.040
Capacity Training	0.11	0.115
Access to Info	0.35	0.083
Access to Extension	-0.55	0.019
Primary Income (Agriculture)	0.34	0.031

The regression of the above variables with the Women's Dietary Diversity Score shows a positive correlation for all variables except Crop Diversity and Access to Extension. Grams of potatoes consumed proved to be highly correlated but not as strongly as with the food security score. The r^2 for this model was 0.10. Although the r^2 values for all models were low, each had multiple statistically significant variables. Therefore, insight was gained in how changes in the variables are associated with changes in food security.

2.6.5 Probability of Adequate Intake

A sensitivity analysis was conducted using the range and mean iron concentration from predominant potato varieties in the Huancavelica region. Total iron intake of respondents' diets without potatoes (in red) and with the medium potato concentration is shown in Figure 2.10. Iron intake from potatoes varied greatly among respondents. Potatoes are the main source of iron for many respondents, even supplying enough to meet the minimum daily iron requirement in some cases.

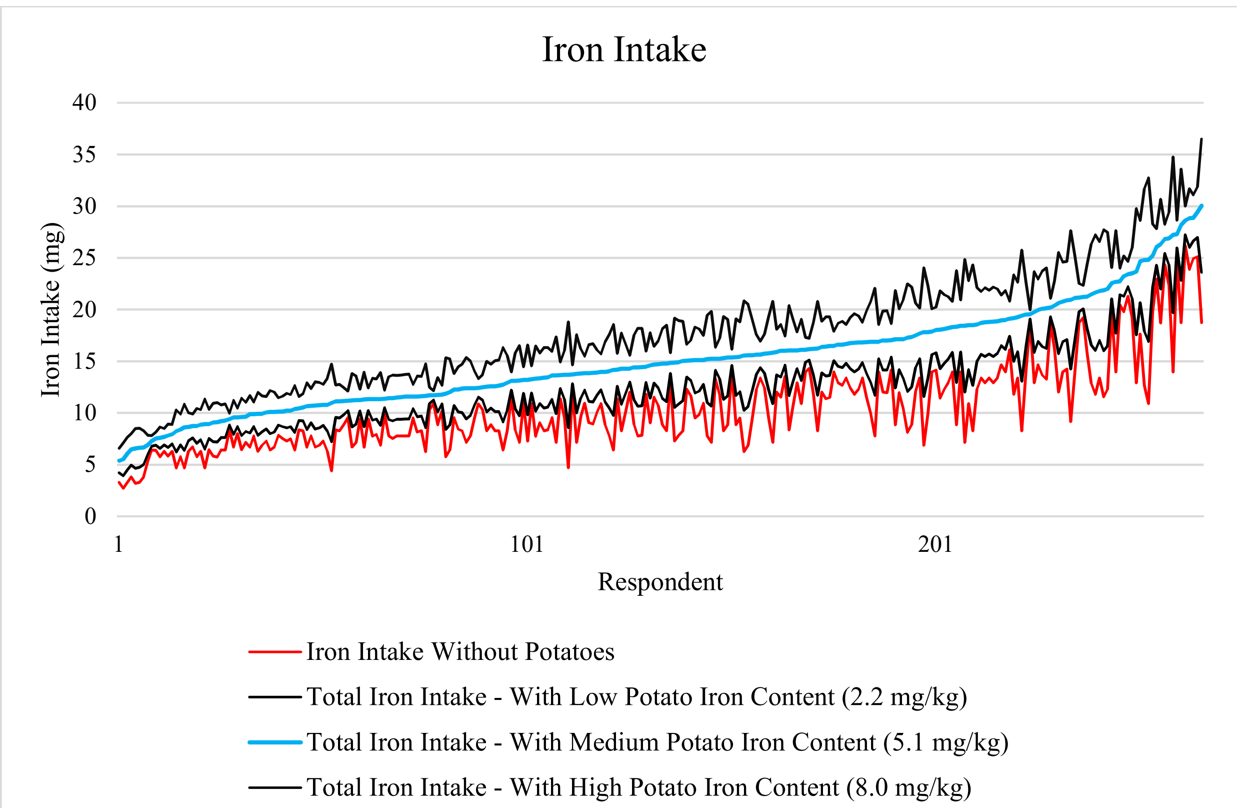

Figure 2.10. Survey respondents' total iron intake in the last 24 hours from total food consumption and consumption without potatoes

Using the full probability approach, per the Institute of Medicine's (2001) recommendations, the probability of inadequacy was calculated using the three iron concentrations (2.2 mg/kg, 5.1 mg/kg, and 8.0 mg/kg) (Table 2.10). The full calculations for each full probability approach are shown in Appendix I. The low- and high-intake represents consumption of potato cultivars with the lowest and highest iron concentration, while medium uses the mean iron intake of the 12 predominant potato cultivars.

Table 2.10. Probability of inadequate iron intake calculated by using the full probability approach and three possible iron concentrations (2.2 - 8 mg/kg).

Iron Concentration in potato	**Probability of Inadequacy**
Low (2.2 mg/kg)	0.65
Medium (5.1 mg/kg)	0.48
High (8.0 mg/kg)	0.35

Respondents who ate multiple potato varieties, which happened to be most respondents, likely fell into the 'Medium' category. The full probability approach estimates that just under half of the population (48%) is consuming an inadequate amount of iron. Using the medium iron concentration, 5.1 mg/kg, the average iron intake was 15.1 mg/day. Shifting consumption from medium iron concentration to high results in a reduction of 17% iron inadequacy in the population. Shifting consumption from low iron concentration to high results in a reduction of 30% iron inadequacy in the population. As consumption continues to shift to more nutritious potatoes, probability of inadequacy continues to decrease, as shown in Figure 2.11.

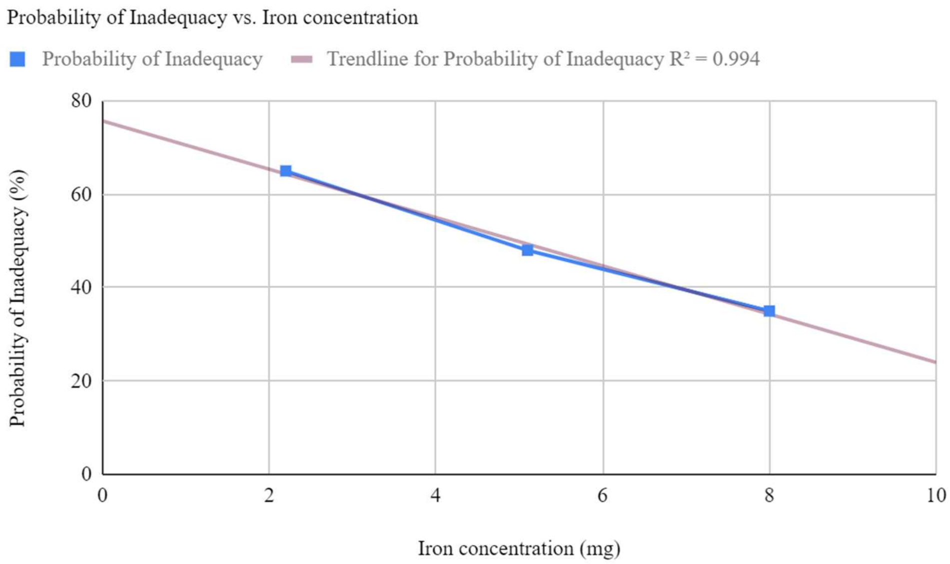

Figure 2.11. Probability of population with inadequate iron intake based off average iron concentration of potatoes consumed

Analyzing the breakdown of probability of inadequacy vs dietary diversity, there is a decreasing trend as dietary diversity increases (Figure 2.12).

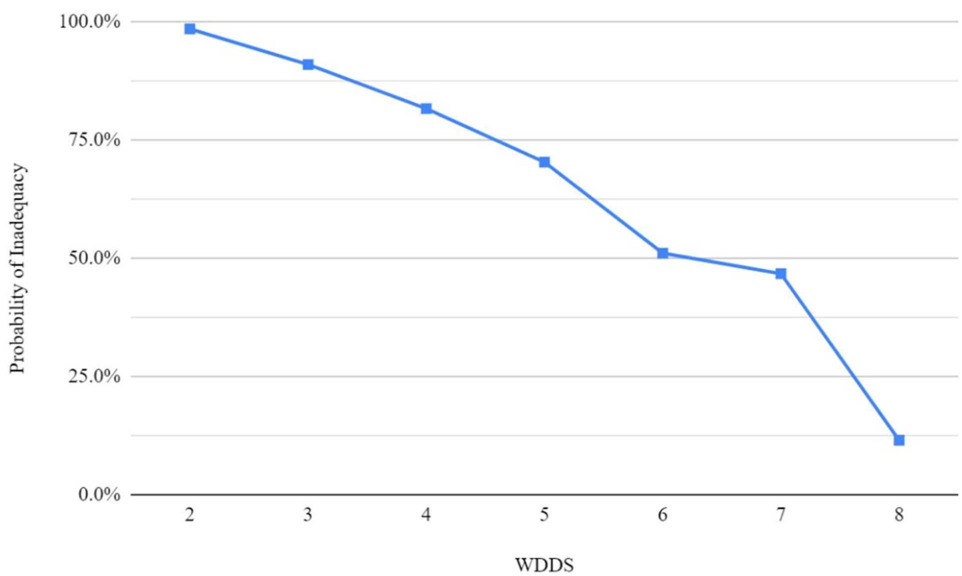

Figure 2.12. Probability of participants having inadequate iron intake based off recommendations from FAO's Women's Dietary Diversity Score

2.7 Discussion

The region of focus for this study is unique in that many families reported having high food security, with 39% of the households having a score of 0-2. This may be explained by the fact that this is the most productive potato growing region in Peru, and all households in the study produced potatoes. Households heavily depend on this staple crop to meet basic caloric needs, especially those with a lower socioeconomic status, due to its high availability and accessibility in local markets.

The average food security score of 3.18 shows that many respondents still feel lacking when it comes to food security. A lack of dietary diversity may play a part, as indicated in question 5 of the US Household Food Security Survey Module – "For lack of money or other factors, have you ever had a diet with a small variety of foods? (Variety of foods means that they are different foods)" (Appendix D). While the US Household Food Security Survey Module has been shown to be an accurate measure of food security, it has also been proven to not fully capture certain cultural or social contexts impeding food security; several subdomains are missing such as feelings of shame, alienation and helplessness, as well as food acquisition in a socially acceptable ways (Jones et al., 2013). The decision to not use the universal cutoff categories of low, medium and high food security, as is done with the US Household Food Security Survey Module in the United States, was based on recommendations by Coates and colleagues (2006). Instead, the food security score was used in the analysis as a continuous variable, to account for variation in response patterns across communities.

Dietary diversity was relatively high considering the region's dependence on potatoes. However, the significant correlation between legumes and the food security score shows that respondents are highly dependent on legumes as well. The non-heme iron content of legumes may provide some dietary iron but due to its low bioavailability, the iron content may not be enough to satisfy the daily requirement. Organ meats provide the most bioavailable iron, yet this food group was only consumed by 9% of the respondents. Seventy percent of respondents indicated they ate flesh meat in the past 24 hours, yet no information regarding the quantity is known. Chicken and guinea pig are perhaps the most commonly eaten flesh meats in the Andes, yet their iron content is still low compared to organ meats (Table 2.3).

The simplicity of the Women's Dietary Diversity Score requires many assumptions about serving sizes for food items. There was no minimum intake requirement for indicating consumption of food items, therefore dietary diversity scores may be overestimated. One way to combat this problem in future studies would be to require a 10-g minimum intake for all food groups, as was done for the study by Kennedy et al. (2007). This study proved that the two dietary diversity scores (no minimum intake and 10-g minimum intake) were in fact very similar. However, the correlation between the 10-g diversity score and the indicator for adequate micronutrient intake was stronger than that for the simple diversity score. This change could greatly improve the accuracy of the results, particularly in the Andean highlands context. For example, using a minimum intake requirement for *caldos* (typical Andean soup) would eliminate items that are negligible within the soup. One limitation of the study is that the Women's Dietary Diversity Score relied solely on the respondent's memory; therefore, recall bias may affect the responses. This is a tradeoff that must be considered in cases where the project has a small budget for baseline and monitoring and evaluation surveys.

Another limitation to this survey is that responses to the Women's Dietary Diversity Score could vary drastically depending on the time of year, with an ample amount of food readily available right after harvest and an extreme shortage during other parts of the year.

Administering this survey to the same households during different times of the year could provide a more thorough understanding of food and nutritional security in this region.

Multiple regression of socioeconomic variables on the food security score show crop diversity and food security to be negatively correlated (Table 2.8), indicating higher crop diversity leads to higher food insecurity. There may be a number of explanations for this, but perhaps due to the large variety of potatoes in the region, households are unaware that they are growing unproductive varieties. Since potatoes play a key role in the region, growing nutritious varieties that are pest- resistant is especially important. One of the main outcomes of the IssAndes project was the identification of 27 native potato varieties with high iron and zinc content (Appendix F). Replacing low micronutrient varieties with these predominant varieties could increase iron intake and ultimately improve nutritional status if coupled with other strategies. Additionally, growing higher yielding potatoes that are more resistant to pests will lead to improved food security.

The second strongest correlation was between education and food security. Rampant malnutrition among developing countries is partially due to the lack of knowledge around how to obtain these sources of nutrients and how the human body uses them (Ruel, 2003). Iron from animal sources (heme iron) is highly bioavailable (20-30 percent) while iron from plant sources (nonheme iron) is absorbed much less easily. This low absorption rate (2-10 percent) is due to the presence of compounds such as phytic acid, tannins and certain dietary fibers in plant sources that inhibit iron absorption (Allen & Ahluwalia 1997; Hallberg, 1981).

Most Andean households depend on staple crops for most of their total daily intake of energy and micronutrients. These staple crops (i.e. cereals and starchy roots, tubers, and legumes) contain nonheme iron, thus bioavailability is low (Gibson, 1994). Additionally, these crops also contain large amounts of phytic acid. Therefore, strategies to reduce the amount of phytic acid in the diet along with increasing the amount of heme iron is crucial to food based strategies.

Food based strategies aim to combat food and nutritional insecurity from every angle. One important strategy is by educating the population on what causes anemia and child stunting, then identifying important foods to combat this phenomenon can be very effective in this region. Nutrition education targeted at women of childbearing age should emphasize the importance of consuming a diverse diet rich in micronutrients. Additionally, these programs should highlight the importance of consuming other food groups, aside from potatoes. Perhaps the most important food groups for women of childbearing age are those that contain heme iron. Of the 266 households in this study, 186 reported rearing at least 1 animal. Since the availability of these food groups is there, households must make the decision to consume their livestock rather than sell it. Behavior changes such as this one can be done through nutritional education. An emphasis must be placed on diversifying their diet and consuming more heme-iron containing foods.

Those that owned their own house also tended to have higher food security. Other respondents indicated either renting or living with their parents. Households in these situations may have to sell most of the potatoes they produce to pay rent. In these scenarios, households could greatly benefit from access to credit and loans.

Multiple regression of the socioeconomic variables on Women's Dietary Diversity Score indicate access to extension is negatively correlated to dietary diversity (Table 2.9). A deeper look into this correlation is needed to fully understand this phenomenon. However, perhaps one explanation would be that extension services disproportionately promote potato consumption, albeit more nutritious varieties. A shift in extension educators' objectives to increase knowledge of the overall food system could greatly improve household's dietary patterns. Extension services could help disseminate information about what specific varieties do best in their respective environment, and how to mitigate for a changing climate and other agronomic issues.

As with the food security score, the Women's Dietary Diversity Score is negatively correlated to crop diversity. However, studies have shown that promotion of home gardens, small livestock production and fish ponds are proven to increase the production of micronutrient rich foods (Chakravarty, 2000; Marsh & Runsten, 1998; Ruel, 2003). Home gardens are a popular initiative due to the dual purpose of both increasing household food supply and dietary quality.

Calculations for the probability of inadequate intake show that if respondents were to shift their consumption of potatoes from low or medium to high iron concentration varieties, a significant improvement in iron intake (30% of the population) would result. Institutions such as the International Potato Center could focus on breeding superior potato varieties. Even a 1 mg increase of iron concentration in potatoes would reduce inadequate iron intake on a population level (Figure 2.11). This important finding could benefit research institutions working to improve potato varieties, as well as extension services helping communities who are suffering from nutritional insecurity. Increasing the concentration of certain minerals and nutrients, while reducing the concentration of inhibitors, could potentially result in substantial changes to populations whose diet primary consists of that one staple food item. While this is a more costly approach, it has the potential to reach a large population and may be more cost-effective.

A more detailed comparison of how the characteristics of each variety compare to each other would be an important next step in this study. For example, if a high iron concentration variety has a low productivity, households may be better off producing a medium or even low concentration variety with a higher productivity. Therefore, the household would have the option to sell half the harvest and consume the rest, as opposed to selling the whole harvest. Another characteristic worth investigating would be concentration of other essential nutrients, such as zinc. If a low iron concentration variety is high in other essential nutrients, then a shift to eating only one variety may result in other nutrient deficiencies. Shelf life is another characteristic that could impact a household's decision to consume or sell the varieties they produce.

The most accurate assessments to determine nutritional security rely on biochemical diagnostic tests of blood or urine, which, although the most accurate, can be challenging to implement, time consuming and expensive to collect and analyze. This chapter demonstrates that a simple diversity score can be manipulated and used to assess population level iron inadequacy. To test the accuracy of this method, a comprehensive nutritional assessment should be conducted for one or more of these communities and the results should be compared to the results shown in this report. Further accuracy can be achieved through this simple assessment by using a 10-gram minimum intake requirement or adjusting for seasonal variation. The decision about the level of detail to incorporate into a survey will depend on the project budget, time and resources available for survey administration and the overall project goals and objectives. With these limitations in mind, the most comprehensive way to tackle overall food and nutritional security is to adopt a variety of approaches.

The aim of this study was to use a simple food and nutritional security assessment to calculate inadequate iron intake for communities primarily dependent on potatoes. This study transformed the diversity score into a daily iron intake and used the full probability approach to calculate inadequacy. A sensitivity analysis was conducted using different potato varieties to understand how the shift in potato consumption shifts population level iron inadequacy. The results show that potato consumption is significantly correlated with both the dietary diversity and food security score (Table 2.8 & 2.9). A significant shift in nutrition occurs when respondents change their consumption of potatoes to varieties higher in iron (Table 2.10 & Figure 2.11). Furthermore, there is a strong negative association between increased dietary diversity and iron inadequacy (Figure 2.12).

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Conclusion

Food and nutritional security continue to be a serious concern in the highlands of Peru. Traditional farming techniques are unlikely to change as the high elevation makes other subsistence and horticulture crops unable to grow at this altitude (FAO, 2015). Communities in this region rely heavily on potatoes as their main staple food to meet minimum caloric intake. Anemia is a chronic problem in the region occurring in 43% of children under the age of 5, and 21% of women of childbearing age (Ordinola et al., 2014).

Due to the prevalence of hidden hunger and its dire consequences, it is imperative to combat this phenomenon in the most productive way possible. This paper presented a standardized food and nutrition security assessment to calculate inadequate iron intake for communities primarily dependent on potatoes. Results from this study show that food security is relatively high within these communities, but consumption of critical nutrients, such iron is very low. Calculations for the probability of inadequate intake show that if respondents were to keep their daily diet the same but only shift their consumption of potatoes from low or medium to high iron concentration varieties, a significant improvement in the probability of inadequate iron intake would result in the population.

In addition, this paper addressed food-based strategies to reduce micronutrient deficiencies in the Peruvian Andes. While there is no single strategy or intervention that exists to eliminate micronutrient deficiencies, a food-based approach that aims to increase production, consumption, and bioavailability of food high in iron and other essential nutrients is vital to combat food and nutritional security in the highlands of Peru.

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Appendix A: Production Survey

Escala de Inseguridad Alimentaria para mujeres

Ahora voy a hacerle algunas preguntas sobre los alimentos que ustedes consumen en casa.

24	**¿Cuál de las siguientes alternativas describe mejor respecto a los alimentos en su casa,** en los últimos 12 meses**?** **LEA LAS ALTERNATIVAS:**	Siempre comen lo suficiente y los alimentos que quieren	1
		Comen lo suficiente pero no siempre lo que quieren	2
		A veces no comen lo suficiente	3
		Frecuentemente no comen lo suficiente	4
		No sabe	9

PARTE A: ESCALA DE SEGURIDAD ALIMENTARIA

Ahora le voy a hacer algunas preguntas referidas a situaciones que podrían haberse presentado en su hogar en los **últimos 12 meses** por falta de dinero u otros factores que han limitado el acceso a alimentos y usted me debe contestar **SI** o **NO**.
Durante los **últimos 12 meses:**

	Preguntas para la madre	Sí=1,	No=0,
25	Por falta de dinero u otros factores (falta de alimentos, pérdidas en la producción, escasez en los mercados, sequías, inundaciones, falta de agua), ¿alguna vez usted se preocupó que en su hogar se quedaran sin alimentos?	0	1
26	Por falta de dinero u otros factores, ¿realmente alguna vez en su hogar se quedaron sin alimentos?	0	1
	REFERIDO A ADULTOS DE 18 AÑOS O MÁS		
27	Por falta de dinero u otros factores, ¿alguna vez usted o algún adulto de su hogar dejó de tener una alimentación nutritiva y saludable?	0	1
28	Por falta de dinero u otros factores, ¿alguna vez usted o algún adulto de su hogar tuvo una alimentación con poca variedad de alimentos? (VARIEDAD DE ALIMENTOS, significa que son diferentes alimentos)	0	1
29	Por falta de dinero u otros factores, ¿alguna vez usted o algún adulto de su hogar dejó de desayunar, almorzar o cenar?	0	1
30	Por falta de dinero u otros factores, ¿alguna vez usted o algún adulto de su hogar comió menos de lo que está acostumbrado a comer?	0	1
31	Por falta de dinero u otros factores, ¿alguna vez usted o algún adulto de su hogar sintió hambre pero no comió?	0	1
32	Por falta de dinero u otros factores, ¿alguna vez usted o algún adulto de su hogar comió solo una vez o dejó de comer todo el día?	0	1
	REFERIDO A NIÑOS Y JOVENES DE 0 A 17 AÑOS		
33	Por falta de dinero u otros factores, ¿alguna vez algún menor de 17 años de su hogar dejó de tener una alimentación nutritiva y saludable?	0	1
34	Por falta de dinero u otros factores, ¿alguna vez algún menor de 17 años de su hogar tuvo una alimentación con poca variedad de alimentos?	0	1
35	Por falta de dinero u otros factores, ¿alguna vez algún menor de 17 años de su hogar comió menos de lo que está acostumbrado a comer?	0	1
36	Por falta de dinero u otros factores, ¿alguna vez algún menor de 17 años de su hogar tuvo que disminuir la cantidad servida de alimentos en cada comida?	0	1
37	Por falta de dinero u otros factores, ¿alguna vez algún menor de 17 años de su hogar sintió hambre pero no comió?	0	1

SI RESPONDE **"NO"** A LAS PRIMERAS CUATRO PREGUNTAS FIN DE LA SECCIÓN

38	Por falta de dinero u otros factores, ¿alguna vez algún menor de 17 años de su hogar se acostó con hambre?	0	1
39	Por falta de dinero u otros factores, ¿alguna vez algún menor de 17 años de su hogar comió solo una vez o dejo de comer todo el día?	0	1
REFERIDO A LOS NIÑOS de 0 A 5 AÑOS			
40	Por falta de dinero u otros factores, ¿alguna vez algún menor de 5 años de su hogar dejó de tener una alimentación nutritiva y saludable?	0	1
41	Por falta de dinero u otros factores, ¿alguna vez algún menor de 5 años de su hogar tuvo una alimentación con poca variedad de alimentos?	0	1
42	Por falta de dinero u otros factores, ¿alguna vez algún menor de 5 años de su hogar dejó de desayunar, almorzar o cenar?	0	1
43	Por falta de dinero u otros factores, ¿alguna vez algún menor de 5 años de su hogar comió menos de lo que está acostumbrado a comer?	0	1
44	Por falta de dinero u otros factores, ¿alguna vez algún menor de 5 años de su hogar tuvo que disminuir la cantidad servida de alimentos en cada comida?	0	1
45	Por falta de dinero u otros factores, ¿alguna vez algún menor de 5 años de su hogar sintió hambre pero no comió?	0	1
46	Por falta de dinero u otros factores, ¿alguna vez algún menor de 5 años de su hogar comió solo una vez o dejó de comer todo el día?	0	1

OTROS FACTORES: SE REFIERE A OTRO FACTORES POR LOS CUALES EL HOGAR SE HA VISTO LIMITADO EN SU ACCESO A ALIMENTOS ENTRE LOS CUALES PODEMOS MENCIONAR: DISPONIBILIDAD DE ALIMENTOS ALMACENADOS, ALIMENTOS PARA EL AUTOCONSUMO, PÉRDIDAS EN LA PRODUCCIÓN, FALTA DE ALIMENTOS EN LOS MERCADOS, DESASTRES NATURALES COMO INUNDACIONES Y SEQUÍAS, HELADAS, FALTA DE TRANSPORTE, FALTA DE AGUA, ROBO DE GANADO, ENFERMEDADES DE LAS PLANTAS (RANCHA). etc.

DIETA SALUDABLE Y NUTRITIVA: ES CUANDO SE COME DIFERENTES TIPOS DE ALIMENTOS, PRINCIPALMENTE FRUTAS, VERDURAS, LÁCTEOS Y HUEVO. TAMBIÉN IMPORTA EL NÚMERO DE COMIDAS QUE CONSUME DURANTE EL DÍA, DEBE SER 3 COMIDAS PRINCIPALES, POR LO MENOS.

Score de inseguridad alimentaria

Appendix B: Nutrition Survey

SECCIÓN N° 1: CONSUMO DE ALIMENTOS DE LA MADRE.

1. Preguntar a la madre o mujer responsable que cocina para la familia, pero estamos interesadas en que específicamente que comía ELLA como persona vulnerable. Recordatorio de ayer para grupos de alimentos, y medir diversidad.
Preguntar por todo lo que comió en la casa, ayer desde que se levantó hasta que durmió, preparaciones e ingredientes, apunta en el primer cuadro, y luego marcar los grupos y número de comidas:

Hora	Nombre de la preparación y sus ingredientes y/o Alimento consumido

No=0, Sí=1

A	Arroz, Pan, Galletas, Tallarines (incluye sopas instantáneas), Maíz o Comidas hechas de Maíz, Avena, Cebada u otras Comidas hechas de Granos.	0	1
B	Papa, Chuño, Moraya, Yuca, harinas (de papa, chuño, etc.)	0	1
C	Zapallo, Zanahorias, Camote Amarillo (fuentes Vitamina A)	0	1
D	Frijoles, Lentejas, Soya, Tarwi, Habas, Arveja (fresca o seca), Garbanzos.	0	1
E	Hojas verde -oscuras (Espinaca, Acelga, Atajo, Albahaca)	0	1
F	Mango, Papaya. (Frutas fuentes de Vitamina A)	0	1
G	Cualquier otro tipo de Fruta (ejemplo: Manzana, Plátano, Mandarina, Naranja, etc.) o Vegetal (ejemplo: Cebolla, Tomate, Apio, etc.)	0	1
H	Hígado de Pollo, u otras Vísceras de Pollo u otro Animal	0	1
I	Cualquier tipo de carne: Res, Cerdo, Pollo o Pato, Cuy, Alpaca, Vizcacha (frescos o secos).	0	1
J	Pescado fresco o algún Producto del Mar o Río, Pota.	0	1
K	Huevos	0	1
L	Queso, Yogurt, Cuajada, Leche, Requesón u otros Productos Lácteos.	0	1
M	Aceite, Manteca, Mantequilla, Margarina o comidas hechas con cualquiera de éstos.	0	1
N	Chocolates, Caramelos, Tortas u otros Alimentos o Comidas Azucaradas.	0	1

Appendix C: Characteristics of IssAndes Project Communities (Ordinola et al. 2014)

Departamento	Provincia	Distrito	IssAndes Población Objetivo	Indice de vulnerab. Inseg. Alim.	Tasa de `DCI 2009	Pobreza extrema monet. 2007 (%) INAI	IDH 2009 PNUD
Huancavelica	Castrovirreina	Santa Ana	13	0.562	53.29	66.7	0.546
	Huancavelica	Huando	129	0.877	56.27	76.2	0.519
		Nuevo Occoro	83	0.843	62.95	74.7	0.534
		Conayca	10	0.756	51.32	61.3	0.525
		Laria	45	0.643	44.44	67	0.536
		Yauli	22	0.901	57.02	83.6	0.507
		Ascención	6	0.112	53.11	24.7	0.585
		Mariscal Cáceres	12	0.456	46.02	68.3	0.541
Apurímac	Andahuaylas	Huancarama	228	0.691	62.90	17.7	0.559
		Kishuará	150	0.854	38.00	52.5	0.537

Adaptado de: MIDIS. Listado de distritos priorizados para la implementación de intervenciones efectivas para la reducción de la Desnutrición Crónica Infantil (DCI). 2012.

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Appendix D: Adapted US Adult Food Security Module (US HFSSM)*

1. Which of the following choices best describes the food at home, in the last 12 months?
    a. I always had enough to eat and of foods that I wanted
    b. I always had enough to eat but not always what I wanted
    c. Sometimes I did not have enough to eat
    d. Frequently I did not have enough to eat
2. Due to lack of money or other factors (lack of food, production losses, shortages in markets, droughts, floods, lack of water), did you ever worry that your home would run out of food?
   Yes=1, No=0

---

3. For lack of money or other factors, did you ever really run out of food at home?
   Yes=1, No=0

---

4. For lack of money or other factors, did you ever stop having a nutritious and healthy diet?
   Yes=1, No=0

---

5. For lack of money or other factors, have you ever had a diet with a small variety of foods? (Variety of foods means that they are different foods)
   Yes=1, No=0

---

6. Due to lack of money or other factors, did you ever stop having breakfast, lunch or dinner?
   Yes=1, No=0

---

7. For lack of money or other factors, did you ever eat less than you are used to eating?
   Yes=1, No=0

---

8. For lack of money or other factors, did you ever feel hungry but did not eat?
   Yes=1, No=0

---

9. For lack of money or other factors, did you ever eat just once or stop eating all day?
   Yes=1, No=0

**Time frame or reference of all responses is the last 12 months*

Appendix E: Adapted FAO Women's Dietary Diversity Survey

Group	Food items	Yes/No
A	Rice, bread, cookies, noodles (including instant soup), corn or food made from corn, oatmeal, barley or other food made from grain	
B	Potato, Chuño, rehydrated potatoes, flour made from potato, chuño, etc.	
C	Pumpkin, carrots, sweet potato (Vitamin A vegetables)	
D	Beans, lentils, soy, lupini, fava beans, peas (dry or fresh), garbanzos	
E	Dark green leafy vegetables (spinach, chard, basil)	
F	Mango, Papaya (Vitamin A fruits)	
G	Other types of fruits or vegetables	
H	Chicken liver or other organ meats from chicken or other animal	
I	Flesh meat: Beef, pork, chicken, turkey, guinea pig, alpaca, Vizcacha (fresh or dry)	
J	Fish or other ocean or river product, pota	
K	Eggs	
L	Cheese, yogurt, curd, milk, cottage cheese or other milk products	

Appendix F: IssAndes Nutritious Potato Varieties (Ordinola, et al. 2014)

Variedad	Vitamina C mg/100gr BS	Hierro mg/100gr BS	Zinc mg/100gr BS	Comp Fenol Total mg/100gr BS	Antocianinas Total mg/100gr BS	Actividad Antiox. mg Trolox equival/ 100 gr	Materia Seca %
Almidona	48.59	1.63	1.06	757.23	311.77	1248.21	23.34
Amachi	40.93	2.05	1.00	2638.78	1440.21	3559.39	24.95
Azul Soncco	47.49	1.38	0.65	957.27	392.19	1627.91	22.25
Caspas	62.52	1.73	0.86	584.95	102.11	961.52	27.75
Ccepa simpa	60.37	2.18	1.34	322.74	3.02	750.08	24.24
Cuchiaca	47.45	2.06	0.84	985.43	502.37	1428.14	29.96
Gaspar	53.98	1.77	0.76	244.39	2.26	450.52	33.98
Guinda gaspar	50.50	2.41	1.48	448.44	53.92	1121.64	22.61
Huawa suyto	47.77	2.19	1.32	492.64	36.43	640.69	29.98
Leona	52.81	1.82	0.81	1164.88	511.30	1684.29	28.65
Misi maki	30.45	1.78	1.17	725.33	205.25	1230.11	23.53
Muro Millcco	45.03	1.66	0.77	776.18	279.98	1181.58	27.08
Muro piña	40.17	1.81	1.33	378.23	20.12	834.37	23.14
Pasña papa	59.21	2.16	1.38	248.07	2.14	447.39	29.51
Pichiuccollma	53.41	1.76	1.12	645.90	71.89	1278.26	31.71
Puca Mellco	60.67	1.30	0.73	508.80	40.26	1046.51	27.55
Puka puma maki	45.37	2.53	1.68	356.58	19.53	800.96	23.79
Q'e qorani	34.66	1.77	0.84	848.67	198.76	1268.44	34.23
Q'oesullo	54.97	2.76	0.92	680.36	140.20	1886.51	27.92
Señorita	31.04	2.02	0.69	670.40	179.66	1382.19	23.90
Serena	44.45	1.82	1.63	326.98	9.41	580.29	26.31
Suyto yawar soncco	51.41	1.63	1.34	793.65	218.98	1269.14	23.56
Wenccos	45.50	1.49	0.78	761.31	257.51	1472.46	31.74
Yanapasña Pucas Ñawi	69.20	2.32	1.64	350.22	42.62	589.93	27.24
Yawar huaycco	44.28	1.71	0.98	1607.41	584.34	3410.47	24.32
Yuracc piña	51.36	2.34	1.32	784.03	1.69	1275.44	20.50

Ordinola, M., Fonseca, C., Vela, A., Devaux, A. (2014). Desarrollando Innovaciones para la Seguridad Alimentaria y Nutricional con Base en la Biodiversidad. *Centro Internacional de la Papa, Lima, Perú*. 92 pp.

Appendix G: R Script

Pearson Correlation:

```
> cor.test(FAODD$FinSS.x, FAODD$GramsPapa, method=c("pearson"))
        Pearson's product-moment correlation

data:  IronIntake$WDDS and IronIntake$FinSS
t = -3.2346, df = 264, p-value = 0.001373
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.30827948 -0.07677857
sample estimates:
       cor
-0.1952472
```

Multivariate regression of food groups by the food security score (FinSS):

```
> ff <-
lm(FinSS.x~GramsPapa+Legumes+LeafyGreens+Eggs+OtherFruits+VitaminAFruitsVeggi
es+Milk+OrganMeats+Meat, FAODD)
> summary(ff)

Call:
lm(formula = FinSS.x ~ GramsPapa + Legumes + LeafyGreens + Eggs +
    OtherFruits + VitaminAFruitsVeggies + Milk + OrganMeats +
    Meat, data = FAODD)

Residuals:
    Min      1Q  Median      3Q     Max
-4.5695 -1.6999 -0.0214  1.6157  5.1901

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)            4.9459339  0.4810261  10.282  < 2e-16 ***
GramsPapa             -0.0008978  0.0002941  -3.052  0.00251 **
Legumes               -0.5854955  0.2816335  -2.079  0.03862 *
LeafyGreens           -0.4037272  0.7696527  -0.525  0.60034
Eggs                  -0.1176349  0.2875899  -0.409  0.68285
OtherFruits           -0.3792385  0.2884016  -1.315  0.18970
VitaminAFruitsVeggies -0.1025902  0.3043314  -0.337  0.73632
Milk                  -0.0187552  0.3017336  -0.062  0.95049
OrganMeats            -0.4972943  0.4823120  -1.031  0.30348
Meat                  -0.3937891  0.3164123  -1.245  0.21444
```

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.234 on 256 degrees of freedom
Multiple R-squared:  0.08184, Adjusted R-squared:  0.04956
F-statistic: 2.535 on 9 and 256 DF,  p-value: 0.008406
```

Appendix H: Backward Stepwise Regression

Backward stepwise regression of socioeconomic variables by the food security score (FinSS):

```
> library(MASS)
> finreg <-
lm(FinSS.x~Age+Housing+GramsPapa+dependent+diversity+SexofJefe+AgeofJefe+EduofJefe+EduofMadre+
+                totalmembers+CapacityTraining+CommParticipation+WaterAccess+
+
Papaforconsume+AccesstoInfo+AccesstoExtension+PrimaryIncome+Climate+AnimalCrianza + x, data=Dependent)
> back_finreg <- stepAIC(finreg, direction = "both", trace=FALSE)
> back_finreg$anova
Stepwise Model Path
Analysis of Deviance Table

Initial Model:
FinSS.x ~ Age + Housing + GramsPapa + dependent + diversity + 
    SexofJefe + AgeofJefe + EduofJefe + EduofMadre + totalmembers + 
    CapacityTraining + CommParticipation + WaterAccess + Papaforconsume + 
    AccesstoInfo + AccesstoExtension + PrimaryIncome + Climate + 
    AnimalCrianza + x

Final Model:
FinSS.x ~ Housing + GramsPapa + diversity + EduofJefe + EduofMadre + 
    WaterAccess


                  Step Df    Deviance Resid. Df Resid. Dev      AIC
1                                           244   1170.148 435.5663
2          - dependent  1 0.009611725       245   1170.158 433.5685
3      - AnimalCrianza  1 0.015669535       246   1170.174 431.5720
4          - AgeofJefe  1 0.088769794       247   1170.262 429.5921
5          - SexofJefe  1 0.098958868       248   1170.361 427.6145
6            - Climate  1 0.441588312       249   1170.803 425.7145
7       - AccesstoInfo  1 0.554993203       250   1171.358 423.8401
8  - AccesstoExtension  1 0.376437417       251   1171.734 421.9253
9   - CapacityTraining  1 0.476822352       252   1172.211 420.0331
10       - totalmembers  1 0.701834507       253   1172.913 418.1917
11 - CommParticipation  1 0.908203096       254   1173.821 416.3968
12      - PrimaryIncome  1 1.924206684       255   1175.745 414.8308
13                  - x  1 1.700442827       256   1177.446 413.2138
14     - Papaforconsume  1 2.964371957       257   1180.410 411.8802
15                - Age  1 3.814979492       258   1184.225 410.7352
> full_finreg <-
lm(FinSS.x~Housing+GramsPapa+diversity+EduofJefe+EduofMadre+WaterAccess,
data=Dependent)
> summary(full_finreg)

Call:
lm(formula = FinSS.x ~ Housing + GramsPapa + diversity + EduofJefe + 
```

```
    EduofMadre + WaterAccess, data = Dependent)

Residuals:
    Min      1Q  Median      3Q     Max 
-4.3601 -1.5999  0.0749  1.4677  5.1629 

Coefficients:
                Estimate Std. Error t value Pr(>|t|)    
(Intercept)    4.7204430  0.6426834   7.345  2.7e-12 ***
HousingPropia -0.5248025  0.3019366  -1.738 0.083382 .  
GramsPapa     -0.0009764  0.0002719  -3.591 0.000394 ***
diversity      0.1444755  0.0878155   1.645 0.101143    
EduofJefe      0.0097952  0.0036782   2.663 0.008231 ** 
EduofMadre    -0.0105952  0.0039784  -2.663 0.008228 ** 
WaterAccess   -0.0073421  0.0046542  -1.578 0.115901    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.142 on 258 degrees of freedom
Multiple R-squared:  0.1284,   Adjusted R-squared:  0.1081 
F-statistic: 6.334 on 6 and 258 DF,  p-value: 3.119e-06
> wddsreg <- 
lm(WDDS~Age+Housing+GramsPapa+dependent+diversity+SexofJefe+AgeofJefe+EduofJe
fe+EduofMadre+
+    totalmembers+CapacityTraining+CommParticipation+WaterAccess+
+    
Papaforconsume+AccesstoInfo+AccesstoExtension+PrimaryIncome+Climate+AnimalCri
anza+x, data=Dependent)
> back_wddsreg <- stepAIC(wddsreg, direction = "both", trace=FALSE)
> back_wddsreg$anova
Stepwise Model Path 
Analysis of Deviance Table

Initial Model:
WDDS ~ Age + Housing + GramsPapa + dependent + diversity + SexofJefe + 
    AgeofJefe + EduofJefe + EduofMadre + totalmembers + CapacityTraining + 
    CommParticipation + WaterAccess + Papaforconsume + AccesstoInfo + 
    AccesstoExtension + PrimaryIncome + Climate + AnimalCrianza + 
    x

Final Model:
WDDS ~ GramsPapa + diversity + AgeofJefe + CapacityTraining + 
    CommParticipation + AccesstoInfo + AccesstoExtension + PrimaryIncome


               Step Df    Deviance Resid. Df Resid. Dev      AIC
1                                        244   376.5911 135.1290
2         - Housing  1 0.000633905       245   376.5917 133.1294
3  - Papaforconsume  1 0.007057100       246   376.5988 131.1344
4         - Climate  1 0.013536996       247   376.6123 129.1439
5               - x  1 0.068141582       248   376.6805 127.1919
6       - dependent  1 0.283994715       249   376.9645 125.3916
7    - totalmembers  1 0.150655608       250   377.1151 123.4975
8       - SexofJefe  1 0.326637141       251   377.4418 121.7269
9     - WaterAccess  1 0.663982604       252   378.1058 120.1927
```

```
10   - AnimalCrianza  1 0.909442560       253   379.0152 118.8293
11       - EduofJefe  1 2.024494735       254   381.0397 118.2410
12             - Age  1 2.242996921       255   383.2827 117.7964
13     - EduofMadre  1 2.070940488       256   385.3536 117.2244
```

Backward stepwise regression of socioeconomic variables by Women's Dietary Diversity Score (WDDS):

```
> full_wddsreg <-
lm(WDDS~GramsPapa+diversity+AgeofJefe+CapacityTraining+AccesstoInfo+AccesstoE
xtension+PrimaryIncome, data=Dependent)
> summary(full_wddsreg)

Call:
lm(formula = WDDS ~ GramsPapa + diversity + AgeofJefe + CapacityTraining +
    AccesstoInfo + AccesstoExtension + PrimaryIncome, data = Dependent)

Residuals:
   Min     1Q Median     3Q    Max
-2.717 -0.884  0.004  0.781  4.091

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)        4.7200246  0.3441867  13.714   <2e-16 ***
GramsPapa          0.0003758  0.0001567   2.399   0.0172 *
diversity         -0.1014347  0.0505024  -2.009   0.0456 *
AgeofJefe         -0.0163422  0.0079112  -2.066   0.0399 *
CapacityTraining   0.1090414  0.0688695   1.583   0.1146
AccesstoInfoSi     0.3452576  0.1984696   1.740   0.0831 .
AccesstoExtension -0.5497005  0.2328163  -2.361   0.0190 *
PrimaryIncome      0.3408847  0.1572562   2.168   0.0311 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.229 on 257 degrees of freedom
Multiple R-squared:  0.09931,	Adjusted R-squared:  0.07477
F-statistic: 4.048 on 7 and 257 DF,  p-value: 0.0003148
```

Appendix I: Full Probability Approach Calculations

low concentration

PI	Iron Intake (mg)		No. of respondents	Percentage of Respondents	Percentage x PI
1	7.5		29	10.9%	10.9%
0.96	7.5	8.4	14	5.3%	5.1%
0.93	8.4	9.4	28	10.5%	9.8%
0.85	9.4	10.7	35	13.2%	11.2%
0.75	10.7	11.8	31	11.7%	8.7%
0.65	11.8	12.9	22	8.3%	5.4%
0.55	12.9	13.9	22	8.3%	4.5%
0.45	13.9	15.1	24	9.0%	4.1%
0.35	15.1	16.6	26	9.8%	3.4%
0.25	16.6	18.7	12	4.5%	1.1%
0.15	18.7	22.5	13	4.9%	0.7%
0.08	22.5	26.7	8	3.0%	0.2%
0.04	26.7	31.5	2	0.8%	0.0%
0		31.5	0	0.0%	0.0%
				Probability of Inadequate Intake	65.2%

med concentration

PI	Iron Intake (mg)		No. of respondents	Percentage of Respondents	Percentage x PI
1	7.5		9	3.4%	3.4%
0.96	7.5	8.4	7	2.6%	2.5%
0.93	8.4	9.4	12	4.5%	4.2%
0.85	9.4	10.7	20	7.5%	6.4%
0.75	10.7	11.8	32	12.0%	9.0%
0.65	11.8	12.9	15	5.6%	3.7%
0.55	12.9	13.9	22	8.3%	4.5%
0.45	13.9	15.1	24	9.0%	4.1%
0.35	15.1	16.6	35	13.2%	4.6%
0.25	16.6	18.7	35	13.2%	3.3%
0.15	18.7	22.5	32	12.0%	1.8%
0.08	22.5	26.7	13	4.9%	0.4%
0.04	26.7	31.5	10	3.8%	0.2%
0		31.5	0	0.0%	0.0%
				Probability of Inadequate Intake	48.0%

high concentration

PI	Iron Intake (mg)		No. of respondents	Percentage of Respondents	Percentage x PI
1	7.5		2	0.8%	0.8%
0.96	7.5	8.4	6	2.3%	2.2%
0.93	8.4	9.4	6	2.3%	2.1%
0.85	9.4	10.7	9	3.4%	2.9%
0.75	10.7	11.8	17	6.4%	4.8%
0.65	11.8	12.9	19	7.1%	4.6%
0.55	12.9	13.9	21	7.9%	4.3%
0.45	13.9	15.1	15	5.6%	2.5%
0.35	15.1	16.6	26	9.8%	3.4%
0.25	16.6	18.7	36	13.5%	3.4%
0.15	18.7	22.5	60	22.6%	3.4%
0.08	22.5	26.7	27	10.2%	0.8%
0.04	26.7	31.5	15	5.6%	0.2%
0		31.5	7	2.6%	0.0%
				Probability of Inadequate Intake	35.4%