Using mixed methods to assess food security and coping strategies: A case study among smallholders in the Andean region

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Introduction

'Zero hunger' is the second of the seventeen development goals adopted in the sustainable developments goals agenda (SDGs). The achievement of food security was identified as a key component for accomplishing this goal (UNDP 2015). Food security, as defined in the World Food Summit (1996), is achieved when '*all people at all times have physical and economic access to sufficient, safe and nutritious food that meet their dietary needs and food preferences for a healthy and active life*'. Food security is multidimensional with four core dimensions or pillars namely: availability, access, stability and utilization. A hierarchy across these dimensions has been recognised, with food availability (i.e. existence of a reliable and consistent source of quality food) at the top. However, the quantification of food availability provides only a partial assessment of food security if other essential components such as physical and economic access, proper utilization and stability are not considered (Barrett 2010).

A number of quantitative instruments have been developed for use as proxy indicators of food security at household level, they include 'Food Security and Vulnerability Analysis' (FSVA), 'Household Food Insecurity Access Scale' (HFIAS), 'Food Consumption Score' (FCS) and 'Household Dietary Diversity Score' (HDDS) (Coates et al. 2007; VAM unit 2003; Kennedy et al. 2013; VAM unit 2008). These instruments have been developed by various international agencies, at different times and with different objectives, rendering it difficult to compare them. Qualitative methods have occasionally been used to understand the local context before developing a quantitative instrument, in order to make sure it is appropriate for the study site (Coates et al. 2006). Two comprehensive reviews of the most commonly used instruments have been carried out (Carletto, 2013; Jones 2013). Briefly, although most household indicators are relatively straightforward to apply, these tools only assess two of the food security dimensions (availability and/or access) and they are not always applicable to settings different from those for which they were originally developed. Although some of these instruments could potentially be used in a longitudinal design to assess stability over time, a methodology to assess all food security dimensions during a one-off visit is still lacking.

Mixed methods research involves an integrated investigation using both quantitative and qualitative data in the same study in order to provide a better understanding of the research problem (Creswell and Plano Clark 2011). Approaches to research using this methodology have been used successfully in various disciplines; in the Andean region specifically, studies using mixed methods have been conducted to investigate animal disease reporting (Limon et al. 2014) and to understand the effects of poverty on children (Boyden and Bourdillon 2011). Surprisingly, mixed methods designs have not been widely used in the context of food security. We propose that a

holistic approach, combining quantitative and qualitative data gathering, analysis and integration, is needed in order to capture and evaluate the four dimensions of food security during a one-off visit. In order to demonstrate the applicability of a mixed methods approach to assess food security, as well as the main coping strategies used when food security is compromised, we present a case study in selected areas of the central Andean region in South America (Bolivia, Ecuador and Peru).

The case study was conducted during the first stage of transnational program for the progressive control of Foot and Mouth disease (FMD) in the Andean region. The program was implemented by the Food and Agriculture Organization of the United Nations (FAO) and the governments of Bolivia, Colombia, Ecuador, Peru and Venezuela between 2010 and 2014. The majority (80%) of the farmers in the region are smallholders, which are farmers that derive their livelihood from mixed crop-livestock systems utilising mainly family labour; animals and crops production play diverse roles contributing to smallholders' livelihoods not only through income generation, but also directly as a source of food for home consumption and as a strategy for risk diversification. Seasonal migration of some household members (either to the cities or neighbouring countries) is a common practice to generate off-farm income (Randolph et al. 2007; Upton 2004; Ellis 1993; Rushton et al. 2006). It was expected that by controlling FMD smallholders' food security would improve in all countries (FAO 2011b); yet the food security status of smallholders in the region was not evaluated before the project was launched.

Food security is an essential step to achieve nutritional security. In the three countries where the case study was conducted, a number of national programs and policies have led to a reduction in the number of undernourished people during the last decade (Hines 2014; Mejia Acosta and Haddad 2014). However, UNICEF estimates for the period 2008-2012 showed that nearly a third of children in Ecuador and Bolivia and a fifth in Peru were still stunted (i.e. chronic malnutrition as a result of suboptimal health and/or inadequate diets in quantity or quality), with the main burden and its life-long consequences concentrated in rural areas (UNICEF 2014). By controlling diseases that limit livestock production, it could be expected that households would have greater access to animal-source food (ASF), which has been found to be positively correlated with child growth and cognitive performance (Dror and Allen 2011; Murphy and Allen 2003; Allen 2013; Neumann et al. 2007). Due to the good quality protein and micronutrient profile, ASF have the potential to substantially improve their food and nutrition security (FAO and OIE 2012; FAO IFAD and WFP 2013; FAO 2008; Barasa et al. 2008; Knight-Jones and Rushton 2013). However, the consequences of animal disease control programmes on smallholders' food and nutrition security remain unclear, and the potential contribution of disease control on food consumption is rarely explored. It is therefore

important to develop and test methods to evaluate smallholders' food security, and to further understanding of how smallholder food security can be integrated in animal disease control programmes. The study presented here intended to generate a baseline assessment of smallholders' food security, so potential changes could be evaluated in the future.

The two aims of the case study presented here are (i) to demonstrate the application of mixed methods as an approach to evaluate the four pillars of food security and coping strategies in food security compromised situations in a one-off visit and (ii) to assess the food security of smallholders in the Andean region at the beginning of a transnational programme that could be used as baseline information for future evaluations.

Methods

Study settings and study design

The study was carried out in selected areas of the central part of the Andean region in South America (comprising Peru, Bolivia and Ecuador) within the context of a Regional Project for the progressive control of FMD in the Andean region (FAO 2011b). The project was implemented by the FAO and the governments of the Andean countries between 2010 and 2014 and had three main components: (i) to support the veterinary services of each country to improve disease surveillance, laboratory diagnostics, vaccination programmes and risk mitigation strategies, (ii) to facilitate and improve regional coordination and countries collaboration to contribute to the progressive control of FMD and (iii) to improve risk communication at different levels of the production chain. It was anticipated that by supporting these countries on the progressive control of FMD, smallholder food security wold improve. However, a food security assessment, prior commencing the project, was not conducted.

A mixed methods design was used (Creswell and Plano Clark, 2011). Quantitative and qualitative strands were implemented during the same phase of the research process, giving equal priority and emphasis to each strand. The strands were analysed independently. Quantitative and qualitative results were combined to assess two of the four food security dimensions (access and availability). Results from the qualitative strand were used to assess the remaining two dimensions (stability and utilization) and coping strategies, highlighting differences and similarities across smallholders clusters identified as part of the quantitative strand analysis. A traditional quantitative research design was adopted using stratified multistage random sampling for the selection, within

each of the 3 study areas, of households to be included in the study. A study area was selected within each country based on the a-priori risk of entry and spread of FMD: Cochabamba high valleys in Bolivia, Tumbes in Peru and the area comprising Santo Domingo, Los Rios and Guayas in Ecuador (SD-LR-G-Ecuador). A map illustrating the study areas is presented as supplementary material (Figure S1). Using the PCP-FMD stages classification (FAO 2011a), the study areas in Peru and Bolivia were in stage 4 (FMD virus was not present in the area and there had not been FMD reported cases) and the study zone in Ecuador was in stage 2 (FMD was endemic with presence of clinical cases but control measures had been implemented) when the study was conducted. In each of the study areas, the smallest administrative division for which a list was available from the central government was obtained ("comunidades" in Bolivia, rural "caserios" in Peru and "parroquias" in Ecuador). In the study area in Ecuador, agro-ecological zones ("Tropical", "Subtropical" and "Highland") were used as strata; within each stratum 4 rural "parroquias" and within each of them two smaller division ("recintos") were randomly selected. No stratification was carried out in the study areas of Bolivia and Peru as they were relatively homogeneous from the agro-ecological point of view. For simplicity, the smallest divisions in the three study areas will be referred to as "communities" in the rest of the paper.

After agreement was obtained to conduct the investigation in the community, a sample frame of households was prepared and 10 were randomly selected. If agreement to carry out the investigation was not reached, another community was randomly selected. In order to be included, households had to hold at least one species susceptible to FMD (cattle, sheep, goat and pigs). At each selected household, the aim of the study was explained and verbal consent to participate was obtained. If consent was not given another household was randomly selected. If there were fewer than 10 households in the community with at least one animal susceptible to FMD, all available households were included. Selected households that agreed to take part in the study were visited by two local interviewers: a veterinarian and a social scientist. The aim was therefore to interview 240 households (from 24 communities) in each study area, allowing us to be 99% confident of detecting a certain household characteristic or activity if it was practiced by at least 2% of the households, assuming perfect sensitivity of the means used to ascertain household status (questionnaire). The interviewers were accompanied by a member of the community, who had been proposed by the community leader.

Quantitative and qualitative data collection

Quantitative data were collected by means of a standardised questionnaire. Semi-structured interviews were then conducted in order to build upon information gathered in the initial

questionnaire. Data regarding household demographics, food consumption during the previous week (VAM unit 2008), crops and animal products harvested in the household, food purchased and economic aid received were collected as part of the quantitative strand. Seasonality, food distribution among household members, events or situations that could affect food production and access, as well as coping strategies for such events were explored during the semi-structured interviews (qualitative strand). The questionnaire and semi-structured interview were developed in Spanish. Both were piloted in one community in each country and minor adjustments were made accordingly. The field work was carried out between July 2012 and April 2013 (between July and December 2002 in Cochabamba high valleys - Bolivia, between July 2012 and April 2013 in SD-LR-G-Ecuador and between November 2012 and February 2013 in Tumbes - Peru). Copies of the questionnaire and semi-structured interviews are available upon request. Ethical approval was obtained from the Royal Veterinary College Ethical Committee (URN 2012 0060H).

Quantitative data analysis

Questionnaire data were entered into a relational database in Microsoft Access 2010. Households were described, by study area, in terms of number of animals owned, their production and use of animal and crop products, household composition and off-farm income. Given that many different types of crops were produced across households in the three study areas, only crops that were produced in (i) at least two of the three study areas and (ii) at least 25% of the households in one study area were considered (Table 1). Meat from cattle, sheep, goats, pigs and poultry, eggs and cow's milk were the animal products considered (Table 1). The production and use of each animal product or crop by households was categorised: an animal product or a crop was either (i) not produced in the household or (ii) produced in the household and kept entirely for home-consumption, or (iii) produced in the household and sold (either the entire production or part of it).

Data reduction techniques were utilised to describe the profiles of smallholders based on animal products and crops produced in the household categorised as described above and listed in table 1. As a first step multiple correspondence analysis (MCA) was performed which aims to reduce the dimensions of multivariate data by creating a small number of synthetic, uncorrelated and numerical components describing most data variability (Manly 2005). Given that products considered might influence the numerical components created, products exhibiting little variation across smallholders or products present in less than 25% of the households (outliers) were not considered. MCA was performed separately for each study area due to the high heterogeneity exhibited between these areas in the three countries. However the same set of variables was used in the three study areas to allow comparison. The first three components were retained in Tumbes-

Peru (accounting for 31% of the variance), the first two components in Cochabamba high valleys-Bolivia (accounting for 25% of the variance) and first five components in SD-LR-G-Ecuador (accounting for 42% of the variance). More details are provided in the supplementary material (Table S2.1). Hierarchical cluster analysis (HCA) was then used to group smallholders of each study area into clusters according to their level of similarity in the components created by the MCA. The Euclidean distance was used to assess the level of dissimilarity between two smallholders. The algorithm was agglomerative and the Ward's criteria for linkage was the method used (Manly 2005).

Heterogeneity between clusters was explored for those binary variables that were not included in the MCA and HCA (i.e. supplementary variables) but were considered relevant for some of the food security pillars and/or as coping strategies, namely: (i) having, or not, an off-farm source of income (i.e. income generated from paid jobs, family members sending money from abroad and government aid), (ii) selling, or not, animals (stratified per species) and (iii) purchasing food outside the household (stratified per food group) within the last six months previous to the study. First, Tukey's post hoc comparison between clusters (per study area) was performed. For those that were significant, multivariable logistic regression models were used with the clusters identified from the MCA and HCA as exposure variable. Community to which the smallholder belonged was included as a random-effect to control for correlation within community. Odds ratios were obtained as a measure of strength of association.

In addition, the relationship between having off-farm income and herd size was explored. Firstly herd size was converted to total livestock units (TLU) in order to adjust the scores according to the species hold (i.e. giving the highest weight to cattle and the smallest weight to poultry) (Njuki et al. 2011). Then, the relationship between TLU and off-farm income was assessed including cluster as a fix effect and community as a random effect.

For each household, FCS was calculated as described by the World Food Programme (WFP) (VAM unit 2008) and colour coding was used to identify each food group that comprise the score. Each household food consumption was classified as 'poor' (FCS ≤28), 'borderline' (FSC between 29 and 41) and 'acceptable' (FCS ≥42). In order to further explore dietary diversity within each cluster, boxplots were used to illustrate the variability in the number of days different foods were consumed within each cluster. In addition, a detailed description of the range of products purchased within each food group is provided in in the supplementary material Table S2.3.

Statistical analysis was performed in R 3.0 (R Development Core Team 2013) using packages lme4 (Bates et al. 2013), multcomp (Hothorn et al. 2008) FactoMineR (Husson et al. 2013), Lattice and LatticeExtra (Sarkar and Andrews 2013).

Qualitative data analysis

Qualitative data were analysed using Thematic Analysis which is an inductive approach grounded in the participants' views (Braun and Clarke 2006). This approach provides "rich and detailed, yet complex accounts of data" (Braun and Clarke 2006). It is not allied to a specific theoretical framework and therefore provides a flexible approach to investigating a range of issues. Interviews were transcribed in Microsoft Word 2010 by the social scientist carrying out the interview. Transcripts were read by one member of the research team (*GL*) and interviews that lacked engagement from the interviewee were excluded. The remaining interviews were repeatedly read by two research team members (*GL, DL*) in order to become familiar with participants' accounts of food security. Following this, initial codes for each topic were identified through discussions to capture the salient features of the data (Bazeley 2013). In the next step household interviews were grouped according to the cluster to which the household was allocated by HCA. A subset of 15 interviews from Tumbes-Peru (5 per cluster) were read using the initial codes identified for each topic as a starting point and new codes were identified and added. A subset of 15 interviews from Cochabamba high valleys-Bolivia was read using the same strategy followed by a subset of 15 interviews from Ecuador study area (SD-LR-G-Ecuador). Codes were then applied systematically to the transcripts and the data were rearranged according to codes and clusters in matrices. Finally codes were developed into themes representing the entire data set. Codes and themes were translated into English at this stage and the final themes were re-defined through discussions between 3 members of the research team comprising a veterinary epidemiologist (*GL*), a psychologist (*EGL*) and a nutritionist (*PD-S*).

Results

Smallholder characteristics and classification

The study involved interviewing a total of 632 smallholders from 79 communities (31 in Tumbes-Peru, 23 in Cochabamba high valleys-Bolivia and 25 in SD-LR-G-Ecuador). Some of the selected communities in Cochabamba high valleys-Bolivia (12%) had less than the target of 10 livestock-owning households (mainly as a result of emigration). In addition, some smallholders across the 3 study areas refused to take part of the study. The main reasons given for refusing to participate were lack of time, distrust and no incentive to participate.

Community size varied considerably across study areas: from 30 to 1313 (median=192) households per community in Tumbes-Peru; from 6 to 200 (median=50) in Cochabamba high valleys-Bolivia and from 18 to 300 (median=60) in SD-LR-G-Ecuador. Smallholders were highly heterogeneous between and within communities with respect to number of animals per household, animal products and crops produced in the household, off farm income and household demographics (Table 1).

Following MCA and HCA three clusters were identified in each study area – identified as P-1, P-2 and P-3 for Tumbes-Peru; B-1, B-2 and B-3 for Cochabamba high valleys-Bolivia and E-1, E-2 and E-3 for SD-LR-G-Ecuador. Tables 2 to 4 present the distribution of animal products and crops produced for each cluster in the 3 study areas. A more detailed description of the components retained from the MCA are provided in the supplementary material (Tables S2.1 and S2.2). For simplicity "Producers" are classified as those smallholders that do not commercialise the product harvested (i.e. the product is kept entirely for home-consumption) and "Sellers" are those smallholders that produce and sell either part or all of the production.

In Tumbes-Peru, cluster P-1 included the majority (65%) of smallholders; they were those that sell bananas and keep poultry with poultry meat and eggs used for home-consumption only. Smallholders in cluster P-2 were those that sell bananas and keep pigs and dairy cows selling pork and keeping milk for home-consumption. Smallholders in cluster P-3 produce a diversity of crops and animal products mainly for home-consumption.

In the Bolivian study area, cluster B-1 was composed by potato sellers who kept small ruminants and poultry, using meat and eggs for home-consumption. Smallholders in cluster B-2 were corn sellers who kept poultry and dairy cows, with poultry meat and milk used for home-consumption. Cluster B-3 included the minority of smallholders in the study area (15%) and comprised those smallholders that sell milk and corn, whist producing potatoes for home-consumption.

In the study area in Ecuador, Cluster E-1 comprised most smallholders (76%). Smallholders in this cluster own poultry and dairy cattle, keeping poultry meat and eggs for home consumption and selling milk. Only a small proportion of smallholders (5%) belonged to cluster E-2; these smallholders sell corn and produced milk, pork and sheep meat for home-consumption. Finally smallholders in cluster E-3 were orientated to commercialise their products: rice, meat (cattle and poultry), eggs and milk.

Assessment of smallholder food security

Food availability and food access

As illustrated in the smallholder characterization, household production plays an important role in two dimensions of food security: (i) contributing to food availability and (ii) contributing to food access through income generation that can be used to purchase food.

Based on FCS, all households in Ecuador had "acceptable" household food consumption (i.e. FCS above 42). Four households (1.7%) in Tumbes-Peru had a FCS below 42 and were therefore classified as "borderline" at the time of the survey: one household in cluster P-1, two households in cluster P-2 and one in cluster P-3. Similarly, five households in Bolivia (2.5%) were classified as "borderline", all of them in cluster B-1 (Figure 1). Visits to households with borderline scores were carried out before the rainy season (between the end of November and the beginning of December in Peru and between the end of September and middle of December in Bolivia). There was not geographic pattern with borderline households belonging to different communities. All households that were "borderline" produced mainly crops and dependent upon household production for food availability (i.e. no off-farm source of income). Access to animal protein within these households was intermittent and depended on whether there was a household production surplus, financial resources and access to a vehicle. Interviews with participants reflected these concerns, for example, a participant in P-2 described how "*When there is enough pasture the cows produce more milk and we get some for the household, otherwise milk is just for her calf*". This indicates that restrictions in feeding animals impacted upon the food available in the household. Financial constraints provided another barrier to animal protein consumption, as highlighted in quote from a participant in B-1 "*I live here on my own and do not have any cattle or money to buy meat, so I mainly eat potatoes, peas and chickpeas*". Also implicated was a reliance upon middlemen in the absence of having a car: "*We depend on a middleman coming here, we do not have a car so if I want to sell elsewhere I have to hire a car and it is more expensive*" (P-3).

Although the majority of households across the 3 study areas had a FCS score above 42 at the time of the study, diet diversity varied across clusters. Dairy products were consumed almost every day of the previous week by the majority of households in the Ecuador study area (median in cluster E-1 and E-2 was 7 days and 3 days in cluster E-3). By contrast, only a few households in Tumbes-Peru consumed dairy products (only 5%) and those that did consume milk were mainly smallholders in cluster P-1. Surprisingly almost all households reported that they had consumed meat or fish. However, looking at meat consumption specifically there were some differences across study areas. Red meat was reported to be consumed a median of 4 days a week in cluster B-2 and 3 days a week in cluster B-1 and B2 in Cochabamba high-plateau - Bolivia. Meanwhile smallholders in cluster P-1 and P-2 in the Peru study area consumed mainly white meat (fish and chicken) with a median of 5 days a week in cluster P-1 and P-2 and 3 days a week in cluster P-3. Smallholders in

335 Tumbes-Peru also reported consuming eggs, on average, half of the week but very few reported
336 consuming red meat. Eggs were frequently consumed in all clusters, but particularly in Cluster E-2
337 where eggs were consumed daily (Figure 2). As an observational comparison, all smallholders with a
338 "borderline" FCS consumed meat on fewer days per week than the average smallholder in the same
339 cluster.
340
341 Apart from money generated through the sale of agricultural products harvested in the
342 households, an additional source of money was off-farm income. Within study areas, there were
343 significant differences regarding potential money available in the household from off-farm income
344 across the clusters identified: in Cochabamba high valleys-Bolivia, smallholders in cluster B-3 (milk
345 and corn sellers) had higher odds of receiving money from a family member living abroad (OR 2.8;
346 95% CI 0.84 – 9.41) than those in cluster B-1 (potato sellers and small ruminant meat and egg
347 producers). In Tumbes-Peru, smallholders in cluster P-1 (milk producers and banana and pork sellers)
348 and in P-3 (banana, cassava, poultry, egg and pork producers) had higher odds (OR=2.86 95% CI
349 1.09-5.07 and OR=2.35 95% CI 1.06-7.74 respectively) of having a household member with a paid job
350 than smallholders in cluster P-2 (banana and pork sellers and milk producers). In the Ecuador study
351 area, the odds of a smallholder from cluster E-3 (milk, rice, cattle meat, poultry and egg sellers)
352 having a household member with a paid job was three times as high (OR=3.1; 95% CI 1.29 – 7.27)
353 than that of smallholders in cluster E-1 (milk sellers, poultry and egg producers) (Table 5).
354 In all study areas a general trend was observed, with those households receiving off-farm
355 money having fewer livestock units; the association was statistically significant in Tumbes-Peru
356 (p=0.02) (Table S2.4 Supplementary material).
357
358 There were also significant differences regarding selling live animals. In Cochabamba high
359 valleys-Bolivia, smallholders in cluster B-1 had higher odds of selling sheep (OR=3.09 CI 1.52-6.31;
360 p=0.002) than those in cluster B-2. In Ecuador study area, smallholders in cluster E-3 had higher odds
361 of selling sheep and poultry than those in cluster 1 (OR=11.0 95% CI 1.85-65.61; p=0.008 and
362 OR=7.75 95% CI 7.70-7.79; p=<0.001 respectively).These differences across clusters highlight that
363 food acquisition capacity and the ability of smallholders to cope with a shortage of food production
364 in the household differ across groups of households with different production profile. Although
365 these only suggest association rather than causation, the qualitative strand allowed us to explore
366 these associations in more detail and have a clearer idea of the direction of the effect; these are
367 presented under the sections 'food stability and utilization' and 'coping strategies'.
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Table 6 shows the proportion of households regularly buying food, stratified by food group, within the 6 months prior to the survey. The quantity and quality of the food purchased was not gathered. Main staples and meat were purchased by almost all households. Significant differences were found regarding the purchase of dairy products, pulses and fruit across clusters (Table 6 and 7). Looking at the data on cereals and meat purchased, split by individual products, there are important differences regarding the products bought across clusters (supplementary material table S2.3). For example, within staples, wheat was purchased by a third of smallholders in cluster B-3, but only a fifth in cluster B2 and none in cluster E-2 or any of the clusters in Tumbes-Peru.

Food stability and utilization

The views and experiences of participants, gathered as part of the qualitative strand were used to assess the two remaining dimensions of food security: stability of food consumption and food utilization within the household. The main themes, which influenced variations in food consumption throughout the year were: food available in the household, household financial capacity, household demographics, season and food price (table 8). Unsurprisingly, food available in the household depended on food produced in the household (both plant-based and animal-source foods), and that which was available for purchase. An interviewee in P-3 stated that *"If we do not produce it we have to buy it, but sometimes it is not even available in the market"*, highlighting the multiple constraints upon food availability. A participant in E-2 also describes how food consumption is dependent upon *"what we produce and the fruit that is available".* When circumstances allow households will consume more, as reflected in this quote from a participant in P-2, *"When we can we eat well, a nice barbecue for example, we do, but sometimes it is not possible, depends on the situation"*.

Household financial capacity depended on the money obtained from selling household production (part or all), as well as off-farm income. This was also dependent upon demand and the work currently available, as described by an individual from E-3, *"There are no jobs at the moment, so we do not have enough money… sometimes we have enough money and we eat better, other times we eat less, sometimes we do not have enough even to buy sugar"*. Selling household production provides an income to purchase food for the household: *"I go to the market to sell bananas and from the money I got I buy food for the next couple of weeks"* (P-2).

Household demographics play an important role in the capacity for some family members to go and work elsewhere in order to bring extra food to the household. For example, a participant in B-1 states that *"When my sons come to visit me they bring food"*, while a father working away in Tumbes provides for a family in P-1, "*My dad works in Tumbes and he brings fish, chicken, gas...*

everything we need from Tumbes". Conversely, a lack of family or community support can have negative consequences. For example, a smallholder in E-3 describes how, *"I had an accident and broke a leg and an arm, for 1 year I could not move and I did not have anybody to help me"* (E-3)

The seasons also affected food availability and earning potential, as well as the type of food that may be produced. A smallholder in B-1 describes "*I only produce milk during the rainy season and we keep it to consume it in the household*". For some smallholders seasons with extreme weather conditions can have catastrophic consequences, as outlined by a smallholder in P-1, "*This year it was a tragedy, the river overflowed and ruined all the banana and rice plantations… all the crops were ruined and left us with no money…".* However, for some households the cost of food determined consumption to a greater extent than the seasons, as described by a participant in B3; "*The basis of what we eat is what we produce and this is similar all year round… mainly corn… the food we buy depends on the price, if it is expensive we do not buy it, we consume food that is cheap*" (B-3).

When asked about utilization, the participants reported that food was equally distributed across household members in the majority of households in the three study areas. For example, a householder in B-1 stated that *"We divide what we have so we all eat the same"*, this was echoed by a participant in E-1 who said *"We all eat the same"* and P-2 *"All the same, nobody has priority"*. Only a few households reported giving preference to babies or elderly people when food was scarce. One participant in B-1 described how *"We would give preference to the babies"*, while another in E-2 said that *"We give more to the child".* Meanwhile, in P-2 a participant stated that *"We will give more to my dad"*.

Limitations to produce agricultural products

Given the important role that household production plays in three dimensions of food security (availability, access and stability), the limitations that smallholders face in producing agricultural products were explored using data collected during the qualitative strand.

As expected, household production can be affected by the household resources available and external factors such as weather conditions or animal and plant diseases (table 8). However, there were some differences across clusters. The issue of lack of land was mainly mentioned by smallholders in cluster P-1 in Tumbes-Peru. In recent years land has been acquired and fenced by large producers precluding smallholders from grazing their animals in places that were formerly communal. This might explain, to some extent, why smallholders in this cluster tend to produce

mainly bananas and poultry products. These concerns are reflected in the following quotations from a participant in P1, who said that *"There are farmers that have plenty of livestock and they have been buying land that used to be communal and fenced it"* , while another respondent described how *"Now the government is selling all the land… all these fields over there now have an owner"*.

Plant diseases were the main limitation for smallholders in cluster B-1 in Cochabamba high valleys-Bolivia, whose crops had recently been affected by the potato worm; *"In the last year the potato fields got the potato worm, luckily it affected only part of the land this time so we had some left to eat"* (B-1). The threat posed by this disease was echoed by another respondent, who said, *"We get affected by the potato worm… we need potatoes to feed ourselves otherwise we have to sell our animals to buy some food"* (B-1).

Although weather conditions were a limitation mentioned across all clusters, smallholders were affected in different ways. For example, in cluster P-2 in Tumbes-Peru and clusters B-2 and B-3 in Cochabamba high valleys-Bolivia both flooding and drought impacted upon crop production and harvest. A respondent in P-1 described how, *"When it rains a lot we have to make drains before the river overflows otherwise it ruins all the banana plantations".* B-2 also suffered from crop ruin owing to extreme weather conditions, which has had a long-lasting impact upon crop production: *"In the last year we were affected by hailstorms… all potato crops were ruined, we have not recovered yet…"* In B-3 it was droughts which posed the greatest threat; *"We suffer because of the drought; it ruins corn plantations…".*

Meanwhile, in the Ecuador study area the main concern that weather conditions posed was for the health of livestock; *"When it does not rain animals get really thin and get ill"* (E-3). This was also the case in cluster P-2 in Tumbes-Peru, where drought damaged animal health making them more susceptible to illness. This in turn had an impact upon the price of the animal: *"What can we do? When there is a drought animals get ill… when animals are thin they get all kinds of diseases… nobody wants to buy or buys very cheap"* (P-2).

Animal theft was a major concern repeatedly mentioned across clusters. Theft not only threatened livelihoods but householders also feared for their own safety and felt powerless to prevent it. For example a smallholder in P-1 mentioned *"Theft is one of the worst problems, some associations have even closed because of that, and what can we do? These people are armed; we risk our lives if we try to stop them…*" These concerns were echoed by a participant in B-1 *"There are*

thefts everywhere and cattle get stolen" and E-3 *"If people see the animals on their own they take them"*.

Challenges to commercialise agricultural production

The capacity to commercialise products varied across clusters. The main themes identified as challenges to selling household produce were market saturation at the time of selling, lack of capacity to compete in the market, community attributes and household resources (table 9). Low prices at the time of sale were consistently mentioned as a limitation. Most smallholders tend to harvest their products at the same time of year; this increases the product supply and there is a drop in price as a consequence. This is described by a participant in E-1*"The problem is that the price drops when we have to sell and once the harvest is over the price increases"*, and also in relation to milk prices; *"In winter overproduction makes the price drop, plus milk importation makes it difficult to sell our milk"* (E-1).

Low prices are exacerbated by imports and also by a dependence on middlemen to sell products. The smallholders perceive that these middlemen take advantage of the limited opportunities that they have to sell elsewhere. An interviewee in P-1 stated how, *"There is always a buyer, the problem is how much they pay, they always take advantage"*, while these concerns were echoed by a participant in B-3 *"We do not have problems selling it, the problem is that the price is fixed by middlemen and they pay whatever they want"* and in B-1 *"Nowadays there are a lot of potatoes coming from Peru and Colombia and this is making the price drop… middlemen do not want our potatoes anymore"*.

Similarly, the amount and quality produced is unstable; this makes it difficult for smallholders to sell their products elsewhere and to compete with larger producers. Participants in both E-1 and B-3 discussed difficulties with selling milk, with those in E-1 describing how *"Sometimes we are told the milk is not good, so we have to sell it elsewhere"* and those in B-3 stating that *"We got the milk picked up by the milk processor; if the milk is spoiled they will not take it"*. The quality of the animals also affects the products sold, as described by a participant in E-3, *"Sometimes the animal is too small, sometimes too thin, there is always something wrong…"*.

Community attributes and household resources play an important role in the potential opportunities that smallholders have to sell their products. *"Every year during the raining season, January, February, the road is inaccessible"* (P-1). Access to a car posed a particular barrier to selling products as described by a participant in P-1, *"We do not have a car to take the product out, we are*

deep inside the community and when it rains cars cannot come in." Whereas owning a car provided additional selling opportunities; *"I have my own car, so I take the animals to Punata when I want to sell them… it is better to sell them there"* (B-3). The smallholders' inaccessibility to others was also cited as a challenge to selling products, *"We have to find who wants to buy the milk and at what price, they do not come all the way here, we have to take it all the way down"* (E-3). Further, the cost of transport and time invested to get to the market play an important role on the decision making process to sell their product: *"I do not sell, I prefer to keep it and eat it here… one spends money on transport and ends up losing money. It is not worthwhile"* (B-1).

Household demographics also play an important role, with women smallholders facing additional obstacles to selling their products. For example a smallholder in B-1 describes how, *"I sell potatoes and peas… take them to the market and sell it to the middleman, I am a woman living on my own so I cannot leave the house for too long"*, while another female smallholder shares a similar experience; *"I am a single mom with an ill son, so I can't take my animals to the market, last time I did it wild dogs came and ate my sheep"* (B-2).

Finally, in some areas, having a household member affiliated to a union allows the household to get better price for their product; however, not all smallholders can afford the entry fee: *"To sell to that milk processor you must pay 50 dollars to be associated, other milk processors do not ask you to pay anything"* (B-3). Some smallholders also perceive being affiliated as restricting their freedom to sell; *"Because I am not affiliated I cannot sell to the milk processor, so I sell to whoever wants to buy it"* (P-2).

Coping strategies

Coping strategies used when food availability is compromised were explored using data collected during the qualitative strand in order to assess in more detail the capability of maintaining food stability in a shock situation (e.g. adverse climate conditions, animal and plant diseases). The likely actions to be taken when household production is below expected were dependent on household resources, as well as the reason and magnitude of the shortage. The main actions taken to deal with a reduction in production were searching for alternative options to obtain extra money, utilization of household assets (i.e. slaughter or sell animals and/or used food previously stored), reducing food consumption and trying to get food elsewhere (table 10). Looking for a different paid work elsewhere was another common approach mentioned. For example a participant in B-3 said that he would *"…Look for a job as a builder. It depends if you know someone that will give you a job"*,

while a participant in E-2 was going to *"get a job fumigating otherwise I will not have anything to eat"*

Using household assets such as selling animals or slaughtering some animals for meat consumption were also frequently mentioned as a means of obtaining additional resources. For example, a participant in P-1 said that *"I slaughter an animal before it gets too thin and sell the meat per kilo"* while a strategy described by a participant in E-1 was to *"Sell animals. This winter we sold many animals"*

However, selling some animals would depend upon the number of animals owned. Households with a small number of animals would wait as long as possible before selling an animal, as reflected in these quotes from B-2; *"It is a big loss to slaughter a cow, so we would wait until we do not have any other option"* and P-3 *"If you sell your animals you would lose everything because once you spend the money you will have nothing".* When the shortage is due to reduction in seasonal production (e.g. one harvest ruined), resignation, waiting for the next cycle and consuming less food is a common approach. For example, a participants in P-2 said that they "*Prepare the land and seed again*", which is an approach echoed by participants in E-1, "*It is lost… we just sow again*". However, for participants in B-3 the response was to go without, "*Last year when we lost the potato harvest we just eat less*".

Discussion

Most evaluations of food security consider only some of its dimensions, with availability and access most commonly measured. However, food security is multidimensional and in its evaluation should capture all its components (Hoddinott 1999; FIVIMS 2002). By using a mixed methods framework, including both quantitative and qualitative data collection and analysis, we have been able to evaluate, simultaneously, the four dimensions of food security among smallholders in selected areas of the Andean region. Furthermore, this approach has allowed us to identify challenges faced by smallholders to produce and commercialise agricultural products and potential coping strategies used when food security is compromised, providing a clear idea of the local dynamics and baseline information for future evaluations.

FCS captures both, dietary diversity and frequency of food consumption, and considers the relative nutritional importance of different food groups at household level. However, this score provides only a snapshot during a single week and therefore it does not capture stability and seasonal changes. In our study most households had a FCS above 42 (i.e. acceptable) which might

578 suggest that food security is not an issue in the study areas. Nonetheless, it became clear that food
579 stability (a dimension assessed here as part of the qualitative component) was compromised in the
580 three study areas. Therefore, field evaluation of food availability and access by means of the FCS
581 would have underestimated food insecurity if considered as the only measure. In our study, all
582 households that had 'borderline' FCS were visited before the start of the rainy season; therefore, it
583 can be hypothesized that the outcome of measuring FCS would have differed had the study been
584 conducted during different period of the year. The findings of the qualitative strand with regard to
585 stability strongly support this suggestion. Other limitations related to the use of FCS are that it does
586 not differentiate dietary patterns amongst foods within the same food group; for example, although
587 most smallholders in this study reported that they consumed meat, the type of meat consumed (red
588 meat vs. chicken vs. fish vs. eggs) differed considerably between areas. In addition, FCS does not
589 measure the quantity consumed and therefore, cannot quantify the energy and nutrition gap.
590 Finally, FCS at household level does not consider elements related to the food utilisation dimension
591 such as intra-household food consumption, or consumption of food outside the home. In summary,
592 although FCS is a useful tool for rapid assessment of two of the dimensions of food security
593 (availability and access) at one point in time, it provides an incomplete assessment of household
594 food security.
595
596 For smallholders, food availability depends to a great extent on household production (FAO
597 2011c). The clusters identified in this study showed that there are important differences in the
598 household agricultural production (crops and animal products) and in the use of this production
599 (kept for home-consumption vs. commercialization) between clusters within a region. Although
600 individual characteristics of household production might have been lost by grouping smallholders,
601 key differences among smallholders belonging to the same cluster arise during the qualitative
602 strand. Not surprisingly, the amount and diversity of food consumed throughout the year exhibits
603 seasonal variations as a result of changes in food availability. However, as identified in this study and
604 elsewhere (FAO 2011c; HLPE 2013) food consumption during the year is also affected by factors that
605 determine food access such as household resources, household financial capacity and food price. In
606 fact, household characteristics and time of the year were the two main components affecting food
607 access and availability, with households depending solely on home production being the more
608 vulnerable during the dry season.
609
610 Commercialisation of food products mainly depends on access to markets and resources. For
611 example, in the study communities, proximity to a milk processor appears to incentivise milk
612 production and commercialization. Ideally, the revenue from sales of household produce would

613 contribute to an increase in diet diversity and quality (i.e. from different food groups other than the
614 ones already produced in the household) (Hoddinott and Yohanness 2002; Kennedy et al. 2013).
615 However, it is important to note that, if the money generated from sale of agricultural products is
616 not used to buy food or invested in nutrition relevant activities (such as health or education), access
617 to markets might have a negative impact on household food security.
618
619 Even if a market exists, not all smallholders have the same opportunities to sell their
620 products. Market saturation and lack of capacity to compete in the market were the main
621 constraints identified, highlighting the difference in opportunities across smallholders. Improving
622 smallholder capacities and allowing equal access to markets have been identified as important
623 conditions to reduce hunger (UNDP 2015). Community attributes (i.e. topography and road access
624 to the community) and household resources (i.e. means of transport, household demographics and
625 union membership) were the main themes identified during the qualitative strand as barriers or
626 incentives to selling household production. Similar limitations have been found in previous studies
627 among smallholders in Latin America, Africa and Asia (Shiferaw et al. 2014; Steinfeld 2003; FAO IFAD
628 and WFP 2013).
629
630 Off-farm income has been recognised as an important factor to increase herd size and
631 improve production efficiency (FAO IFAD and WFP 2013). Across the study areas smallholders
632 receiving off-farm income had less livestock units. However, when looking at smallholders grouped
633 in clusters, given their production profile, some clusters were more likely to be receiving off-farm
634 income: P-1 (banana sellers and poultry and egg producers and banana, cassava) and P-3 (poultry,
635 egg and pork producers) in Tumbes-Peru and E-3 (rice, cattle meat, poultry, eggs and milk sellers) in
636 Ecuador. Although the correlation between off-farm income, farm size and smallholder production
637 profile should be interpreted with caution, it is important to note that during the qualitative strand,
638 households receiving off-farm income reported to be in a better position to cope with a shortage of
639 food production and therefore, it is less likely that the food security of these smallholders is
640 compromised. This suggests that off-farm income is an important component of household financial
641 capacity, as well as a coping strategy when food production is reduced.
642
643 Food stability depends on the resilience of a household to cope with adverse situations such
644 as price volatility, adverse weather conditions or disease outbreaks. It has previously been noted
645 that coping strategies to deal with food insecurity in the household comprise a sequence of events:
646 first, dietary adjustments such as changing diet, reducing the number of meals or eating smaller
647 portions are usually made. These short-term alterations do not compromise the households' assets

and are easily reversible once food is available again. As food security worsens more extreme strategies are carried out such as the sale of household assets (Tusiime et al. 2013; Maxwell and Caldwell 2008). Strategies such as selling animals might mitigate the problem in the short-term, but they may compromise food access and stability even more in the long-term. Our results are consistent with this pattern, but also showed important differences between smallholders in the decision making process. For example, the decision on whether to sell animals in situations when food availability decreases depends on the species and the number of animals owned; whilst approaches that do not compromise the household assets (such as looking for a paid job elsewhere) were the most common actions taken. Food stability is frequently overlooked during food security evaluations, yet in this study food stability was the main dimension compromised in the three study areas. The qualitative information gathered and analysed in this study, allowed us to evaluate food stability and gain a more genuine assessment of smallholder food security.

Unequal intra-household food distribution is normally related to social norms and practices, and it has been reported as an important factor in food utilization in some parts of the world, compromising the food security of some family members (HLPE 2013). In this study, food distribution within the household was reported to be equal across household members in the majority of households interviewed. However, this should be interpreted with caution as participants may have provided socially desirable responses introducing responder bias. Although more complex qualitative information, such as ethnography, could have provided a more in-depth assessment of this component, collecting and analysing this type of information would have limited the number of smallholders assessed and considerably increased the time required for the assessment. This would have precluded conducting the assessment during one visit. While an ethnographic approach would have given a very detailed understanding of few smallholders, it would limit the generalisability of these findings.

Stunting is still an issue of concern in the three Andean countries where this study was carried out (UNICEF 2014). Food shortage and lack of nutrients at certain stages of pregnancy and childhood has been related to stunted children (UNICEF 2009). Although household food security is one of the conditions to be met in order to achieve individual nutrition security, differences on food access and health status among household members would result in dissimilarities on the individual nutrition status. Making sure that women and children have access to a diverse diet in pregnancy and early childhood respectively would be a key intervention to reduce the number of stunted children and ASFs (i.e. milk, eggs and meat) can be an important source of essential micronutrients. Besides, future studies looking at the impact of animal disease control programmes should explore

links with individual nutrition (particularly maternal and child nutrition) beyond household food security. Integrating anthropometric measures with food access and availability indicators and information on infant feeding practices, food preparation habits, water quality and household members' health, in a single study, would allow to assess the importance of the different pathways to achieve nutrition security in the study area.

In resource-scarce countries, animal disease control programs are often justified on the basis of improving food security for smallholders (FAO 2008; FAO and OIE 2012). For this, smallholders are normally categorised as one homogenous group assuming that, if the control programme were to be successfully executed, smallholders will all benefit equally from it. Our study highlight the complex nature of smallholder food security, which results from the interaction of multiple factors, not all of them related to food availability; similar findings have been reported elsewhere (HLPE 2013). This diversity and complexity means that the potential benefit for smallholders might differ (in terms of food security) following the introduction of livestock disease control programs. Even within this heterogeneity certain patterns exist as shown by the clusters identified in this study, highlighting the importance of understanding local needs and constraints in order to maximise the use of resources. It is therefore important to conduct an assessment of smallholder food security before the animal disease control program starts, so changes in smallholder food security can be assessed at different stages of the program and shortly after the disease has been controlled / eradicated in the area; crucially such assessments should consider all food security dimensions. The results presented here can be used as the base line assessment should the impact of the FMD project in the Region is to be assed in the near future.

Conclusions

This study demonstrates the application of mixed methods as an approach to evaluate food security during a one-off visit, considering its multidimensional nature. Results generated from the case study presented here can provide baseline information for future assessments in the region. Food stability, a dimension frequently overlooked during previous food security evaluations, was deemed the major constraint to smallholder food security in all study areas. Challenges faced by smallholders' precluding stable access to food (identified in this study) can be used to develop policy interventions. Insights gained from this study have applicability beyond the specific case study presented. The methodological approach presented here could be used by policymakers and researchers involved in the design and implementation of disease control programs that aim to improve smallholder food security elsewhere.

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Competing of interest

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Table 1. Smallholder characteristics in each study area. Survey of smallholders carried out between July 2012 and April 2013 in 3 study areas: Tumbes-Peru (n=240); Cochabamba high valleys-Bolivia (n=197) and Santo Domingo, Los Rios and Guayas-Ecuador (n=195)

		Tumbes-Peru (n=240)	**Cochabamba high valleys-Bolivia** (n=197)	**SD-LR-G-Ecuador** (n=195)
Number of animals		Median (1^{st} – 3^{rd} quartile)	Median (1^{st} – 3^{rd} quartile)	Median (1^{st} – 3^{rd} quartile)
Cattle		3 (1 – 7)	3 (2 – 5)	9 (1 – 20)
Sheep		0 (0 – 0)	3 (0 – 10)	0 (0 – 0)
Goats		0 (0 – 6)	0 (0 – 0)	0 (0 – 0)
Pigs		1 (0 – 3)	0 (0 – 2)	1 (0 – 2)
Poultry		16 (7 – 25)	7 (3 – 12)	20 (10 – 40)
Main crops produced in the study areas		***%***	***%***	***%***
Main staples	*Corn* [a]	10.4	74.3	0.5
	Wheat	0	0	27.7
	Rice [a]	10.6	0	27.8
	Cassava [a]	1.9	0.3	27.2
	Potatoes [a]	0	62.8	3.2
Pulses	*Beans*	0	0	0
Fruit and vegetables	*Banana* [a]	54.2	0	28.2
	Lemons	15.5	6.0	11.3
	Cocoa	8.1	0	13.9
Animal products produced in the study areas				
Meat and fish	*Cattle meat* [b]	1.3	2.4	20.6
	Sheep meat [a, b]	5.5	40.8	6.1
	Goat meat [a, b]	10.3	3.6	0
	Pig meat [a]	18.	2.7	28.3
	Poultry meat [a]	78.5	60.6	48.6
	Eggs [a]	79.1	76.8	61.1
Dairy	*Cow milk* [a]	16.3	49.6	78.0
	Sheep milk	0	4.2	0
	Goat milk	0	2.8	0
External economic support		***%***	***%***	***%***
Government aid		3.0	14.0	36.8
Paid job outside the household		30.3	32.2	23.2
Money from family member living abroad		17.3	18.0	5.6
Household composition [c]		Median (min - max)	Median (min - max)	Median (min - max)
Children (up to 15 years old)		1 (0 – 6)	1 (0 – 7)	1 (0 – 8)
Adult men (16 – 60 years old)		1 (1 – 5)	1 (1 – 7)	1 (1 – 6)
Adult women (16 – 60 years old)		1 (1 – 6)	1 (1 – 5)	1 (1 – 4)
Elderly men (> 60 years old)		1 (1 – 2)	1 (1 – 1)	1 (0 – 2)
Elderly women (> 60 years old)		1 (1 – 2)	1 (1 – 2)	1 (0 – 1)

[a] Characteristics used in multivariate analysis for smallholder clusters

[b] Sheep and goat meat combined and considered as small ruminant meat for multivariate analysis

[c] Household composition at the time of the survey

Table 2. Features of Peruvian smallholder clusters identified after MCA and HCA. Data collected as part of the quantitative strand in Tumbes, Peru between July 2012 and April 2013 (n=240)

Crops and animal products [a]	**Cluster P-1** n=157 (65.4%) Banana sellers and poultry and egg producers [b]	**Cluster P-2** n=51 (21.3%) Banana and pork sellers and milk producers [b]	**Cluster P-3** n=32 (13.3%) Banana, cassava, poultry, egg and pork producers [b]
	%	*%*	*%*
Corn			
Do not produce corn	85.4	90.2	53.1
Produce and sell some or all the corn produced	8.3	7.8	25.0
Produce and consume all the corn produced	6.4	2.0	21.9
Rice			
Do not produce rice	94.3	92.2	100
Produce and sell some or all the rice produced	5.7	7.8	0
Produce and consume all the rice produced	0	0	0
Cassava			
Do not produce cassava	99.4	100	59.4
Produce and sell some or all the cassava produced	0	0	0
Produce and consume all the cassava produced	0.6	0	40.6
Banana			
Do not produce bananas	47.8	52.9	21.9
Produce and sell some or all the banana produced	51.0	47.1	18.8
Produce and consume all the banana produced	1.3	0	49.4
Cattle meat			
Do not produce cattle meat	98.7	96.1	100
Produce and sell some or all the cattle meat produced	1.3	3.9	0
Produce and consume all the cattle meat produced	0	0	0
Pork			
Do not produce pork	90.4	60.8	37.5
Produce and sell some or all the pork produced	8.9	37.3	18.8
Produce and consume all the pork produced	0.6	2.0	43.8
Small ruminant meat (sheep and goats)			
Do not produce small ruminant meat	91.1	82.4	84.4
Produce and sell some or all the meat produced	8.9	9.8	15.6
Produce and consume all the meat produced	0	7.8	0
Poultry meat			
Do not produce poultry meat	1.3	74.5	43.8
Produce and sell some or all the poultry meat produced	1.3	13.7	0
Produce and consume all the poultry meat produced	97.5	11.8	56.3
Eggs			
Do not produce eggs	3.2	80.4	40.6
Produce and sell some or all the eggs produced	1.9	9.8	0
Produce and consume all the eggs produced	94.9	9.8	59.4
Milk			
Do not produce milk	94.3	70.6	87.5
Produce and sell some or all the milk produced	3.2	11.8	6.3
Produce and consume all the milk produced	2.5	17.7	6.3

[a] Categories are mutually exclusive

[b] **Producers** are classified as those smallholders that do not sell the product harvested (i.e. is kept for home-consumption); **Sellers** are those smallholders that produce and sell either part or all of the production.

31% variance explained. See S2 for further details

879

880 Table 3. Features of Bolivian smallholder clusters identified after MCA and HCA. Data collected as
881 part of the quantitative strand in Cochabamba high valleys, Bolivia between July 2012 and April 2013
882 (n=197)

Crops and animal products [a]	**Cluster B-1** n=93 (47.2%) Potato sellers. Small ruminant meat and egg producer [b]	**Cluster B2** n=74 (37.6%) Corn and milk sellers. Poultry and egg producers [b]	**Cluster B-3** n=30 (15.2%) Milk and corn sellers. Potato producers [b]
	%	*%*	*%*
Corn			
Do not produce corn	65.6	10.9	10.0
Produce and sell some or all the corn produced	11.8	68.9	46.7
Produce and consume all the corn produced	22.6	20.3	43.3
Potato			
Do not produce potatoes	8.6	50.0	43.3
Produce and sell some or all the potato produced	60.2	12.2	16.7
Produce and consume all the potatoes produced	31.2	37.8	40.0
Pork			
Do not produce pork	98.9	100	83.3
Produce and sell some or all pork produced	0	0	10.0
Produce and consume all pork produced	1.1	0	6.7
Small ruminant meat (sheep and goats)			
Do not produce small ruminant meat	11.8	79.7	93.3
Produce and sell some or all meat produced	1.1	2.7	0
Produce and consume all meat produced	87.1	17.6	6.7
Poultry meat			
Do not produce poultry meat	52.7	8.1	56.7
Produce and sell some or all poultry meat produced	0	0	20.0
Produce and consume all poultry meat produced	47.3	91.9	23.3
Eggs			
Do not produce eggs	28.0	1.4	60.0
Produce and sell some or all egg produced	0	0	23.3
Produce and consume all egg produced	72.0	98.6	16.7
Milk			
Do not produce milk	60.2	35.1	36.7
Produce and sell some or all milk produced	12.9	43.2	60.0
Produce and consume all milk produced	26.9	21.6	3.3

883 [a] Categories are mutually exclusive
884 [b] **Producers** are classified as those smallholders that do not sell the product harvested (i.e. is kept
885 for home-consumption); **Sellers** are those smallholders that produce and sell either part or all of the
886 production.
887 25% variance explained. See S2 for further details

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Table 4. Features of Ecuadorian smallholder clusters identified after MCA and HCA. Data collected as part of the quantitative strand in Guayas, Los Rios and Santo Domingo, Ecuador between July 2012 and April 2013 (n=195)

Crops and animal products [a]	**Cluster E-1** n=148 (75.9%) Milk sellers, poultry and eggs producers [b]	**Cluster E-2** n=9 (4.6%) Corn sellers. Sheep, eggs and milk producers [b]	**Cluster E-3** n=38 (19.5%) Rice, cattle meat, poultry, eggs and milk sellers [b]
	%	*%*	*%*
Corn			
Do not produce corn	75.0	44.4	57.9
Produce and sell some or all the corn produced	17.6	55.6	39.5
Produce and consume all the corn produced	7.4	0	2.6
Rice			
Do not produce rice	68.9	100	47.4
Produce and sell some or all the rice produced	23.0	0	52.6
Produce and consume all the rice produced	8.1	0	0
Cassava			
Do not produce cassava	69.6	77.8	55.3
Produce and sell some or all the cassava produced	4.0	22.2	42.1
Produce and consume all the cassava produced	26.4	0	2.6
Banana			
Do not produce bananas	68.2	77.7	65.8
Produce and sell some or all the banana produced	3.4	0	31.6
Produce and consume all the bananas produced	28.4	22.2	2.3
Cattle meat			
Do not produce cattle meat	91.9	44.4	34.2
Produce and sell some or all cattle meat produced	4.7	22.2	65.8
Produce and consume all cattle meat produced	3.4	33.3	0
Pork			
Do not produce pork	79.7	66.7	78.9
Produce and sell some or all pork produced	12.8	33.3	10.5
Produce and consume all pork produced	7.4	0	10.5
Small ruminant meat (only sheep)			
Do not produce small ruminant meat	95.3	44.4	81.6
Produce and sell some or all meat produced	4.7	0	18.4
Produce and consume all meat produced	0	55.6	0
Poultry meat			
Do not produce poultry meat	50.7	44.4	18.4
Produce and sell some or all poultry meat produced	0	11.1	55.3
Produce and consume all poultry meat produced	49.3	44.4	26.3
Eggs			
Do not produce eggs	27.0	33.3	23.7
Produce and sell some or all egg produced	11.5	0	39.5
Produce and consume all eggs produced	61.5	66.7	36.8
Milk			
Do not produce milk	29.7	22.2	15.8
Produce and sell some or all milk produced	58.8	11.1	50.0
Produce and consume all milk produced	11.5	66.7	34.2

[a] Categories are mutually exclusive

[b] **Producers** are classified as those smallholders that do not sell the product harvested (i.e. is kept for home-consumption); **Sellers** are those smallholders that produce and sell either part or all of the production.

42% variance explained. See S2 for further details

907 Table 5 Results from mixed effects models of association between cluster membership and off-farm
908 income in each study area.

Cluster	OR (95% C.I.)[a]	P value
Tumbes – Peru [b]		
P-1 (N=157)	2.85 (1.09 – 5.07)	0.03
P-2 (N=51)	1	
P-3 (N=32)	2.35 (1.06 – 7.74)	0.04
Cochabamba high valleys – Bolivia [c]		
B-1 (N=93)	1	
B-2 (N=74)	1.79 (0.66 – 4.89)	0.25
B-3 (N=30)	2.81 (0.84 – 9.41)	0.09
SD-LR-G Ecuador [b]		
E-1 (N=148)	1	
E-2 (N=9)	2.98 (0.67 – 13.18)	0.15
E-3 (N=38)	3.12 (1.29 – 7.27)	0.01

909 OR = Odds Ratio; 95% C.I. = 95% confidence interval
910 [a] All models include community as random effect
911 [b] Someone in the household having a paid job elsewhere
912 [c] A family member living abroad and sending money regularly
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Table 6. Number and percentage of smallholders that reported buying food products frequently within the 6 months prior to the survey

Food group	Tumbes-Peru (n=240)			Cochabamba high valleys-Bolivia (n=197)			[a] SD-LR-G-Ecuador (n=195)		
	Cluster P-1 n=157	**Cluster P-2** *n=51*	**Cluster P-3** *n=32*	**Cluster B-1** *n=93*	**Cluster B-2** *n=74*	**Cluster B-3** *n=30*	**Cluster E-1** *n=148*	**Cluster E-2** *n=9*	**Cluster E-3** *n=38*
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Main staples	157 (100)	51 (100)	32 (100)	93 (100)	73 (98.6)	30 (100)	142 (95.9)	9 (100)	127 (97.4)
Meat	157 (100)	51 (100)	32 (100)	91 (97.8)	74 (100)	30 (100)	145 (98.0)	8 (88.9)	37 (97.4)
Dairy	19 (12.1) [b]	14 (27.5) [b]	8 (25.0)	72 (77.4) [b]	50 (67.6)	15 (50) [b]	118 (79.7)	7 (77.8)	34 (89.5)
Pulses	149 (94.9)	47 (92.2)	28 (87.5)	72 (77.4)	60 (81.1)	26 (86.7)	138 (93.2) [b]	6 (66.7) [b]	35 (92.1)
Vegetables	155 (98.7)	51 (100)	31 (96.9)	88 (94.6)	71 (95.9)	29 (96.7)	138 (93.2)	9 (100)	36 (94.7)
Fruit	2 (1.3)	0 (-)	2 (6.3)	81 (87.1) [b]	49 (66.2) [b]	23 (76.7)	66 (44.6) [b]	1 (11.1)	8 (21.1) [b]

[a] Santo Domingo-Los Rios-Guayas-Ecuador

[b] Post hoc comparison showed a significant difference between cluster P-1 and P-2 (P=0.029) in Tumbes-Peru and between cluster B-1 and B-3 (P= 0.014) in Cochabamba high valleys-Bolivia on purchase of dairy products; a significant difference between cluster B-1 and B-2 (P=0.005) buying fruit and a significant difference between E-1 and E-2 buying pulse products (P=0.034) and between E-1and E-3 buying fruit in Santo Domingo-Los Rios-Guayas-Ecuador (P=0.024).

928 Table 7 Results from mixed effects models of association between cluster membership and purchase of food products for products that were statistically
929 significant in the univariate analysis.

Cluster	Dairy products		Pulses		Fruits	
Tumbes – Peru	**OR (95% C.I.)[a]**	**p value**	**OR (95% C.I.)[a]**	**p value**	**OR (95% C.I.)[a]**	**p value**
P-1	1		1		1	
P-2	2.78 (1.14 – 8.82)	0.03	0.63 (0.18 – 2.19)	0.47	0.77 (0.19 – 3.03)	0.71
P-3	2.22 (0.77 – 6.36)	0.13	0.37 (0.10 – 1.33)	0.13	0.47 (0.11 – 1.93)	0.29
Cochabamba high valleys – Bolivia						
B-1	3.33 (1.17 – 9.53)	0.02	1		2.98 (1.06 – 8.42)	0.04
B-2	2.02 (0.77 – 5.31)	0.15	1.39 (0.51 – 3.78)	0.52	1	
B-3	1		1.79 (0.45 – 7.04)	0.41	1.29 (0.41 – 4.05)	0.66
SD-LR-G[b] *- Ecuador*						
E-1	1.29 (1.28 – 1.30)	<0.001	6.89 (1.14 – 31.78)	0.01	1	
E-2	1		1		0.17 (0.01 – 2.65)	0.20
E-3	2.55 (2.53 – 2.56)	<0.001	5.83 (0.94 – 35.99)	0.06	0.38 (0.11 – 1.32	0.13

930 OR = Odds Ratio; 95% C.I. = 95% confidence interval
931 [a] All models include community as random effect
932 [b] Santo Domingo-Los Rios-Guayas-Ecuador
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Table 8. Revised codes and themes identified as factors influencing variation in food consumption. Data collected during the qualitative strand in Tumbes-Peru, Cochabamba high valleys-Bolivia and Santo Domingo, Los Rios and Guayas-Ecuador.

Topic	Codes [a]	Code definition	Themes [a]
Variation in food consumption (Stability dimension)	•Food available for purchase	Food available to buy in the market or with neighbours	Food available in the household
	•Household production	Animal products and crops harvested in the household	
	•Month	Month of the year	Season
	•Special occasions	Festivities such as Christmas and birthdays	
	•Cash from household production	Cash obtained as a result of selling household production (part or all)	Household financial capacity
	•Off-farm income	Money obtained by paid jobs, aid or family living abroad	
	•Household members	Number of household members and their health	Household demographics
	•Family members bringing food	Family members bringing food when visiting or coming back to the household	
	•Food price	Food price at the time of buying	Food price

[a] Codes and themes identified through discussions using Thematic analysis.

958 Table 9 Revised codes and themes identified as challenges and limitations to produce crops/ animal
959 products and to sell household production. Data collected during the qualitative strand in Tumbes-
960 Peru, Cochabamba high valleys-Bolivia and Santo Domingo, Los Rios and Guayas-Ecuador

Topic	Codes [a]	Code definition	Themes [a]
Challenges and limitations to produce crops and animal products	•Lack of land	Land available for animal grazing and crops is limited	Household resources
	•Soil quality	Poor soil quality	
	•Household demographics	Number of adults and age of people living in the household	
	•Household economic resources	Household income including salaries, family support and aid money	
	•Weather conditions	Adverse weather conditions such as drought or flood	External factors affecting product quantity
	•Animal diseases	Animals in the household getting a disease	
	•Plant diseases	Crops affected by a disease	
	•Theft	Theft mainly related to animals	
Challenges and limitations to sell household production	•Demand	Product demand at the time smallholders are selling	Market saturation at the time of selling
	•Product price	Price smallholders receive for product	
	•Middleman	Dependence on middleman to sell the product	Lack of capacity to compete in the market
	•Lack of market	Lack of access to alternative markets to sell production	
	•Instability of production	Changes in production quantities and quality during the year	
	•Amount produced	Amount of animal product / crops produced	
	•Product quality	Quality of the product demanded by the buyer	
	•Roadblocks	Access to/from the community blocked due to demonstrations	Community attributes
	•Access to the community	Topography and roads conditions leading to the community	
	•Means of transport	Means of transport owned to bring production to the point of sale	Household resources
	•Household location	House location in relation with to the point of sale	
	•Household demographics	Number of adults and age of people living in the household	
	•Union membership	Someone in the household being affiliated to a union	

961 [a] Codes and themes identified through discussions using Thematic analysis.

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965 Table 10 Revised codes and themes identified as likely actions taken when household production is
966 less than expected. Data collected during the qualitative strand in Tumbes-Peru, Cochabamba high
967 valleys-Bolivia and Santo Domingo, Los Rios and Guayas-Ecuador

Topic	Codes [a]	Code definition	Themes [a]
Likely actions taken when household production is less than expected	•Wait for external help •Prepare land	Wait for external help / aid Prepare land for next cycle	Resignation and wait
	•Look for a job •Borrow money	Look for a paid job elsewhere Ask for a loan or borrow money from neighbours	Get some cash as emergency measure
	•Slaughter animals •Sell animals •Use reserves	Slaughter some of the household animals Sell some of the household animals Use food previously stored	Utilization of household assets
	•Consume less	Consume less food	Reduce consumption
	•Buy food •Obtain food	Buy food elsewhere Receive food from neighbours	Get food elsewhere

968 [a] Codes and themes identified through discussions using Thematic analysis.

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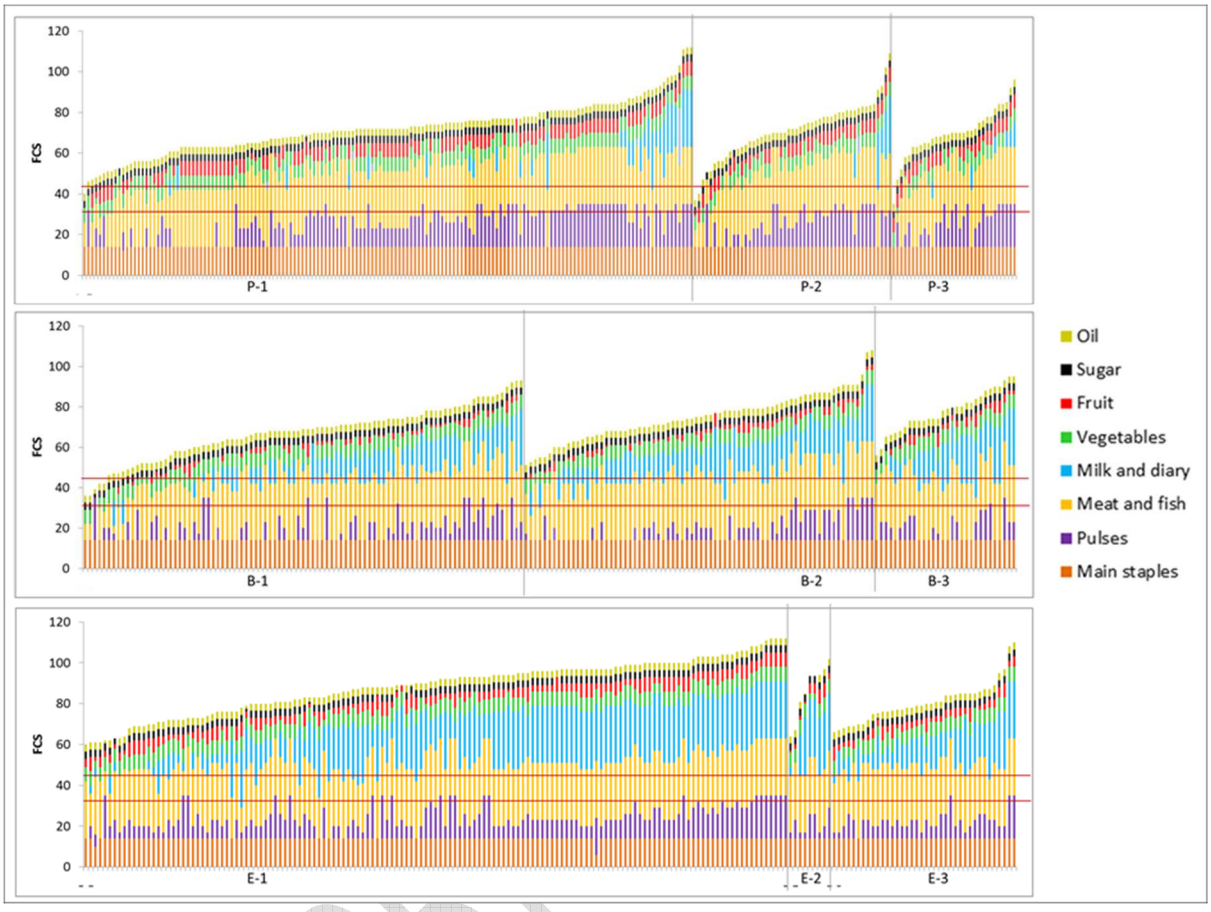

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993 Figure 1. Food consumption score (FCS) for each of the households interviewed stratified by cluster

994 identified in each study area and colour coded per food group. FCS: 0-28 compromised; 28.5-42

995 borderline; >42 secure (VAM unit 2008). The horizontal red lines represent the limits between the

996 three categories.

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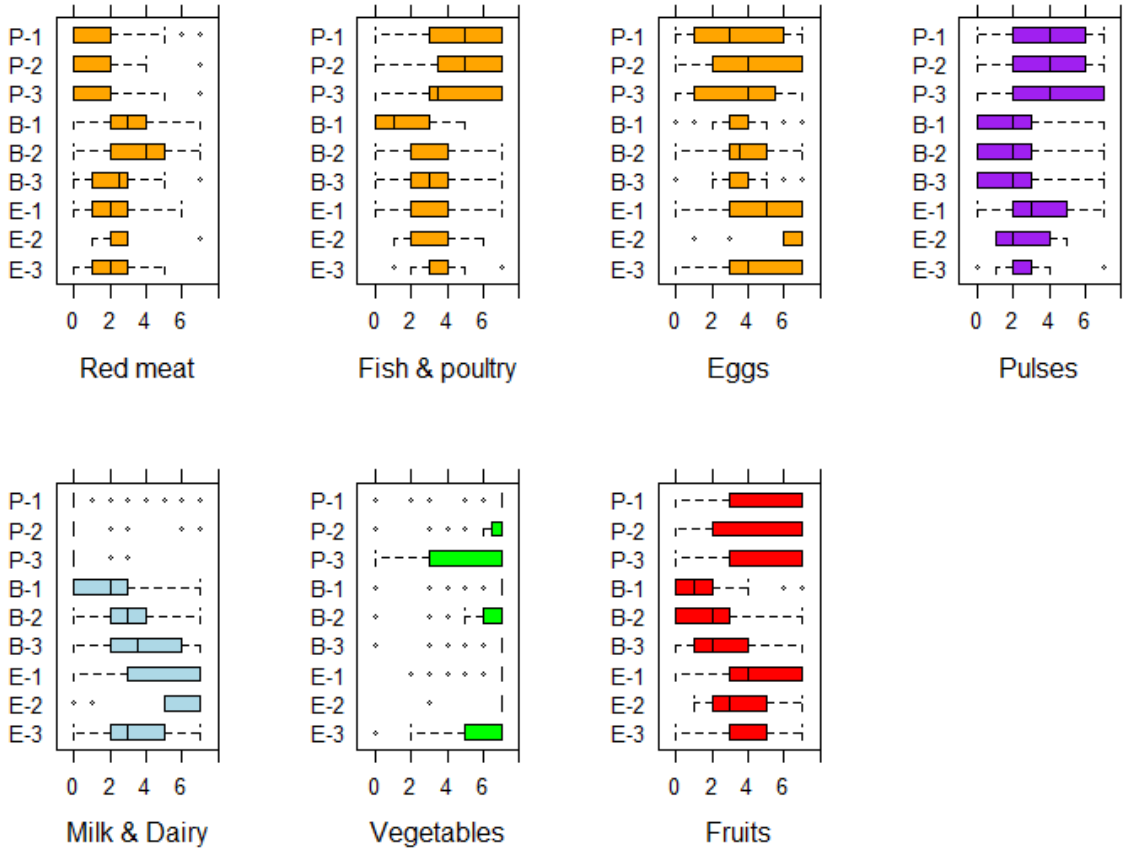

Figure 2. Box plot showing number days per week each food was consumed across clusters. Data collected as part of the quantitative strand in Tumbes-Peru (n=240); Cochabamba high valleys-Bolivia (n=197) and Santo Domingo, Los Rios and Guayas-Ecuador (n=195)