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Unpicking the Inter-relationships Between Off-Farm Livelihood Diversification, Household Characteristics, and Farm Management in the Rural Andes

Mark E. Caulfield[1,2], James Hammond[2], Steven J. Fonte[1], Miguel Angel Florido[3], Walter Fuentes[3], Katherin Meza[1,4], Israel Navarette[5,6,7], Steven J. Vanek[1] and Mark van Wijk[2]*

[1] Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO, United States, [2] Livestock Systems and the Environment, International Livestock Research Institute, Nairobi, Kenya, [3] Fundación Valles, Cochabamba, Bolivia, [4] Grupo Yanapai, Junín, Peru, [5] Department of Plant Sciences, Centre for Crop Systems, Wageningen University and Research, Wageningen, Netherlands, [6] International Potato Centre (CIP), Quito, Ecuador, [7] Knowledge, Technology and Innovation, Wageningen University and Research, Wageningen, Netherlands

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***Correspondence:**
Mark E. Caulfield
markcaulfield11@gmail.com

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Rural households across the world are increasingly turning to off-farm sources of income to complement or replace farm income. A better understanding of these livelihood adaptations, their consequences, and the processes behind them will facilitate more effective rural development policies and projects. The objective of this research was to examine how off-farm income influences rural livelihoods, elucidate factors that determine different livelihood strategies, as well as understand how these livelihood strategies are associated with different approaches to farm management. Using data from 588 Rural Household Multi-Indicator Surveys (RHoMIS) in three rural Andean regions in Bolivia, Ecuador, and Peru, we identified a typology of farming household livelihood strategies, and assessed the differences among these household types with regard to household and farm level characteristics, and farm management. We found that among the household types that incorporated off-farm income into their livelihood strategies, there were significant differences in approaches to farm management. Specifically, we observed an increased use of industrialized farming techniques among one household type, a deintensification, or a stepping-out of farming activities in another household type, and a tendency toward livestock specialization in the other household type. Moreover, our findings revealed that household level characteristics (age and education level of head(s) of household, and household composition) played an important role in mediating which type of livelihood strategy the households employed. For example, "stepping-out" households generally had younger and more educated household heads. Location-specific factors such as access to markets, irrigation, and off-farm employment opportunities were also likely to be highly influential in terms of which pathways farming households adopted as their livelihood strategy. We conclude that rural development

programmes and projects must be driven by the rural communities themselves taking into account this heterogeneity in household characteristics and livelihoods and engaging in the already advanced conversations around different approaches to farming and the conservation of common natural resources.

Keywords: off-farm income, out-migration, rural mobility, rural development, socio-ecological systems

HIGHLIGHTS

- Five hundred and eighty-eight rural household surveys were administered in Bolivia, Ecuador, and Peru.
- Households incorporating off-farm income employed diversified livelihood strategies.
- Livelihood strategies were associated with different approaches to farm management.
- Household head age and education level coupled with location determined livelihoods.
- Off-farm livelihood diversification has important implications for rural development.

INTRODUCTION

In the face of poverty and growing existential threats caused by climate change and land degradation, many rural households are turning to alternative, off-farm sources of income to complement or replace farm income. These off-farm income sources (e.g., construction, commerce, seasonal labor in the agricultural sector, or international migration) are accessed through growing opportunities for temporary and permanent forms of rural out-migration (McDowell and Hess, 2012; Zoomers, 2012; Brandt et al., 2016). Why some households employ one livelihood strategy rather than another, however, remains poorly understood (Gray and Bilsborrow, 2013). A better understanding of these adaptations and the processes behind them will inform more sustainable development strategies aimed at supporting impoverished rural households globally and especially in the developing world (Liu and Xu, 2016; Serrat, 2017).

One narrative that is growing in recognition suggests that, rather than regarding rural out-migration as a flow of people "moving out" of rural areas, it is better conceived as a livelihood adaptation strategy that builds webs of relationships to reduce vulnerability (Zoomers, 2012). Indeed, diversification of rural household livelihood strategies through the generation of off-farm income can prove to be an effective mechanism by which rural households are able to enhance their financial resources, enabling them to remain in the communities in which they grew up. Two recent studies provide important evidence for this insight. Ye (2018) found that rural "stayers" in China developed diversified livelihood strategies based on off-farm income involving multiple jobs and contributing significant amounts to their household livelihoods. While Mata-Codesal (2018) concluded that off-farm income constituted a critical part of complex life strategies that enabled rural households to remain in a village in Mexico.

While many studies focus on the main "external" drivers for livelihood diversification through enhanced rural mobility (Black et al., 2011; De Sherbinin et al., 2011; Gray and Bilsborrow, 2013; Greiner and Sakdapolrak, 2016), others have also highlighted the importance of family and household level characteristics that mediate these drivers of change to rural livelihood strategies. For example, in a recent study based on longitudinal interviews with 553 households in four rural sites in north-west Ethiopia, households with higher levels of education tended to assume livelihood strategies that incorporated long-term out-migration and therefore higher proportions of off-farm income (Tegegne and Penker, 2016). The age of the household head is another important factor that can influence livelihood strategies related to off-farm income generation through temporary migration, with younger household heads more likely to engage in off-farm employment (Carr, 2014; Dodd et al., 2016). Gender and marital status have also been reported to be significant factors (Radel et al., 2012; Carr, 2014; Gray and Bilsborrow, 2014), leading to a "feminization of agriculture," where women are becoming increasingly more engaged in agricultural production and decision-making as men participate more in rural out-migration (Deere, 2005; Lastarria-Cornhiel, 2006; Radel et al., 2012). However, it is important to point out that such trends are not universal. Indeed, in other contexts where off-farm employment opportunities are greater for women than men, the opposite pattern has been observed (McKay, 2005).

Beyond the processes that influence shifts in rural livelihood strategies are the implications of such changes for farm and land management. The growing opportunities presented by rural mobility and associated remittances to rural sending-households have been shown to be accompanied by important shifts in farm and land management (Li, 2013; Gray and Bilsborrow, 2014). However, despite a growing body of research on the subject, the impact of shifting livelihood strategies on farm management remains unclear. Many studies report contrasting effects in terms of adopting more industrialized farming techniques (e.g., agrochemical inputs, tillage) vs. more agroecological approaches as well as changing patterns in land degradation and land conservation (Geist and Lambin, 2002; Mendola, 2008; Gray, 2009; Angelsen, 2010).

For example, in a rural community in the central Ecuadorian Andean province of Cotopaxi, farming households with off-farm income displayed greater use of mechanized tillage, chemical fertilizers, and pesticides compared to households without off-farm income, raising concerns of land-use sustainability (Caulfield et al., 2019). In another study in the Philippines, the involvement of women in off-farm income activities led to the loss of more ecologically sustainable cropping patterns and a transition to more industrialized cropping systems

(McKay, 2005). At the same time, other studies suggest that off-farm income can be associated with farming deintensification. In Chongqing Municipality of Southwest China, households with important off-farm income sources cultivated smaller areas of land with fewer agricultural inputs (Qin, 2010). In another study in the south of Ecuador, households with livelihood strategies that included remittances from international migration tended to invest more in housing and land acquisition than in agricultural productivity (Jokisch, 2002).

These contrasting findings in the literature reveal that the direct and indirect socio-ecological relationships within each unique context and household are important for understanding the responses to broader pressures, their effects on livelihood strategies, and on farm and land management (Geist and Lambin, 2002; Caulfield et al., 2019). Livelihood strategies do not appear to vary in some direct and predictable way with farm management. Instead, distinct livelihood types appear to emerge from a complex set of factors that result in non-linear associations with farm management.

The case of rural communities in Latin America exemplifies many of the challenges of rural communities across the globe and the relationships discussed above. According to a report from the International Labor Organization (ILO), Latin America is the region with the greatest proportion of rural indigenous communities living in extreme poverty (Dhir et al., 2019). In parallel to the challenges posed by such poverty, rural communities in the Andes are also facing critical threats as a result of climate change, land degradation, decreases in agricultural productivity, and shifts in land tenure systems (Perez et al., 2010; Fonte et al., 2012), thus increasing their vulnerability (Montaña et al., 2016). As such, there is a growing trend for rural households in the Andes to assume different livelihood strategies that incorporate off-farm income (Perez et al., 2010; Valdivia et al., 2010; Zimmerer and Vanek, 2016). The objective of this research was therefore to provide greater insight into the influences of increased rural mobility and off-farm income on rural livelihoods in a number of rural communities spread throughout the Andes. Additionally, we sought to elucidate some of the factors that determine different livelihood strategies, as well as understand how different livelihood strategies are associated with different approaches to farm management.

MATERIALS AND METHODS

Conceptual Framework

As conceptualized in **Figure 1**, we hypothesize that: (1) farming household livelihood strategies (defined by a series of farm production and off-farm income activities) are associated with significant differences in farm management approaches; (2) farming household livelihood strategies are associated with differences in household characteristics (e.g., composition, age, education level); and (3) relationships between household and farm level characteristics are context dependent.

Study Sites

In Bolivia (**Figure 2**), the surveys were conducted between September and November 2018 in two administrative "departments" or regions (Chuquisaca and Cochabamba) and three municipalities (Villa Serrano and Alcalá which form part of the Chuquisaca region, and Mizque which pertains to the region of Cochabamba), in the central and southern Andes of Bolivia. The elevation range for the communities in which the surveys were administered was between 1,400 and 2,500 masl, while the average annual temperature varied between a

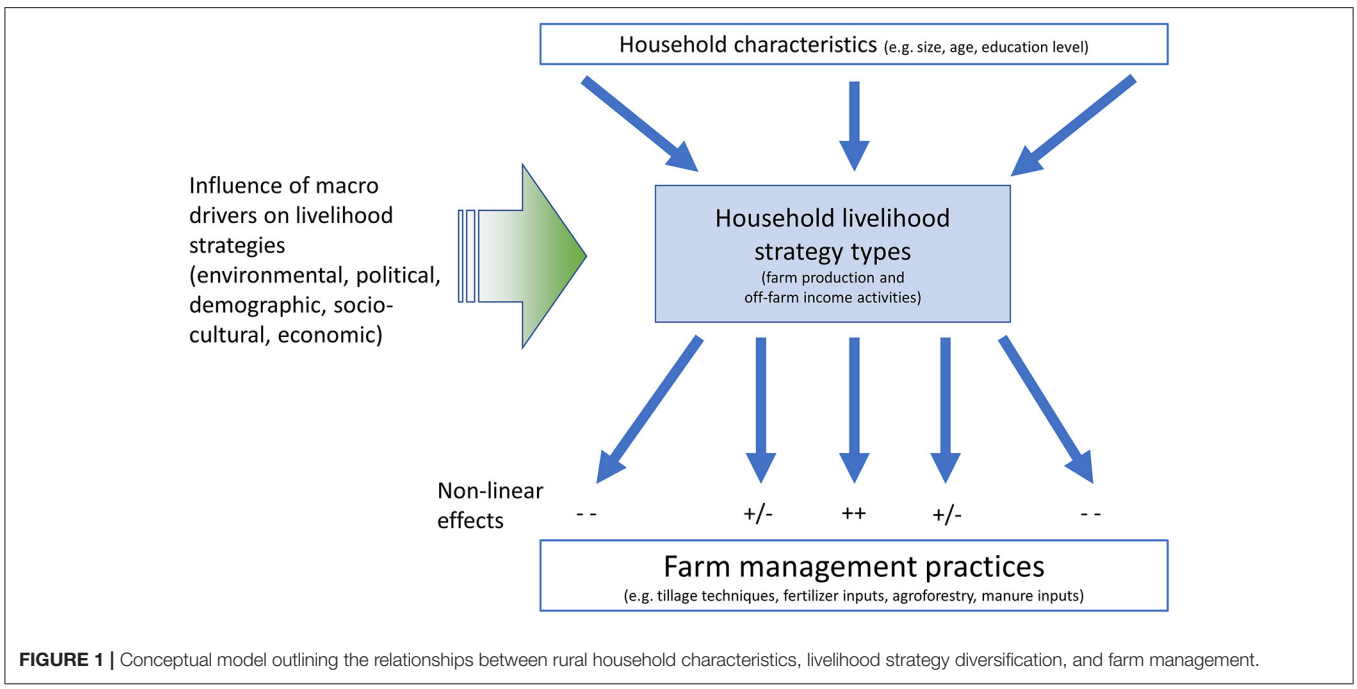

FIGURE 1 | Conceptual model outlining the relationships between rural household characteristics, livelihood strategy diversification, and farm management.

FIGURE 2 | Geographical location of the study sites. Red pins indicate capital cities, blue pins indicate study sites.

low of 16.1°C in a community in Alcalá and a high of 20.6°C in a community in Villa Serrano. Annual precipitation also varied considerably (400–950 mm year^{-1}). There is a dry season from May to October and a rainy season from November to April. According to the local rural development institution that administered the rural household survey, farming systems in the region are mostly small-scale mixed livestock-cropping systems. The main crops cultivated in the region are maize (*Zea mays*), peanuts (*Arachis hypogaea*), potato (*Solanum tuberosum*), bean (*Phaseolus vulgaris*), and wheat (*Triticum aestivum*). Onions (*Allium cepa*), peas (*Pisum sativum*), and fruit trees are also commonly cultivated in Mizque and Villa Serrano. The dominant crop rotation comprises of peanuts, followed by potatoes, and then maize. Small-scale livestock production for home consumption and sale are common, with most households owning some cattle (also used as draft-animals), pigs, and chickens. Sheep are also commonly reared in Alcalá and Mizque. Many households in Alcalá have access to irrigation supplied by rivers or rain water harvesting ponds, but there is no access to irrigation water in Villa Serrano, and only between 10 and 40% of rural households have access to irrigation water in Mizque. Communities surveyed in Alcalá varied in distance to the main municipal market, ranging from 10 to 30 km. Communities in Mizque were located 35–45 km from the municipal agricultural market, while communities in Villa Serrano were located between 20 and 70 km from the municipal agricultural market.

The rural household surveys administered in Ecuador (**Figure 2**) were undertaken between September and October 2018 in four municipalities (Latacunga, Pujili, Salcedo, and Saquisilí) pertaining to the administrative region of Cotopaxi, in central Ecuador. The municipalities are located at elevations between 2,552 and 3,890 masl with temperatures generally ranging between 5 and 20°C. Average annual precipitation rates also vary substantially between 500 and 1,000 mm year^{-1}, with a drier period between June and September and a wetter period between October and May. Farming practices normally comprise of small-scale, mixed livestock-cropping systems. Maize, potato, and forage crops such as barley (*Hordeum vulgare*), vetch (*Vicia sativa*), oats (*Avena sativa*), and alfalfa (*Medicago sativa*) are the dominant crops in the area with most small-scale farming households rotating crops annually or biannually, often concentrating agricultural inputs during the potato crop cycle. Small numbers of cattle are often raised for milk production for self-consumption and for sale to local traders. Cattle are also used for draft power in many households. Other livestock reared for home consumption or sale include sheep, pigs, chickens, and guinea pigs. Access to irrigation varies considerably community by community, with around 70% of rural households

having access to irrigation water in Salcedo, but only 26% in Saquisilí. Market access is also highly variable among locations (between 15 and 70 km to district markets) with better transport infrastructure and services to market found in the municipalities of Latacunga and Salcedo, but poorer market access in Pujili.

Finally, the rural household surveys administered in Peru (**Figure 2**) were undertaken between February and March 2018 in three central Andean municipalities (or provinces) (Huamanga, Acobamba, and Huancayo) pertaining to the administrative regions of Ayacucho, Huancavelica, and Junín, respectively. The communities in which the surveys took place ranged in elevation from 2,800 to 4,500 masl, varying in annual average precipitation between 700 and 1,200 mm year^{-1}, with a wetter period between September and March and a drier period between April and September. As the highest of the three main locations surveyed, the communities in the three municipalities of Peru are also the coldest with average annual temperatures between 9 and 15°C, with temperatures regularly falling below freezing at higher elevations. Farming practices normally comprise of small-scale, mixed livestock-cropping systems. Potato, barley, oats, broad beans (*Vicia faba*), quinoa (*Chenopodium quinoa*), and a variety of Andean tubers [Oca (*Oxalis tuberosa*), Olluco (*Ullucus tuberosus*), and Mashua (*Tropaeolum tuberosum*)] are the dominant crops in the area with most small-scale farming households rotating crops annually or biannually. Multi-year fallow periods within crop rotations remain commonplace in these rural areas of Peru, especially at higher elevations, where fallow periods tend to be even longer (Vanek et al., 2020). Agricultural inputs are often concentrated during the potato phase of the rotation. Cattle, sheep, llamas, and guinea pigs are raised for meat and wool production for self-consumption and for sale to local traders and at markets. Cattle are also used for draft power in many households. Access to irrigation varies considerably between and within communities, with no more than 50% of rural households in each community having access to irrigation water. Access to regional markets is challenging due to distances (up to 125 km) and poor road infrastructure (often only dirt roads for parts of the journey near the communities) and irregular transport services.

Survey Design and Data Collection

The data was collected from the three countries using the Rural Household Multi-Indicator Survey (RHoMIS), a standardized farm household survey used in rural development contexts, and covering topics such as household characteristics, agricultural management and production, livelihoods, and decision making (Hammond et al., 2017; van Wijk et al., 2020; **Table 1**). The survey was tailored to the local context and was applied to 588 farming families across three countries: Bolivia (134 households), Ecuador (284 households), and Peru (170 households) (**Table 2**).

The rural locations for the household surveys formed part of the activities of a group of participating grantees of the Collaborative Crop Research Program of the McKnight Foundation (https://www.ccrp.org/), that jointly decided to assess household level characteristics and farm management for some of the communities in which they are engaged. The study sites selected reflect the great heterogeneity of socio-economic and agroecological rural contexts in the Andes. By compiling data in these disparate contexts in the Andes, it was hoped that the findings of the research would be more generalizable for the broader Andean and global context in developing countries. The sites could be characterized as representing a gradient of farming household market orientation, with the communities surveyed in Bolivia displaying greatest market orientation, and the communities in Peru representing farming households with lower levels of market orientation and with more subsistence farming. The rural communities surveyed in Ecuador could be seen as an intermediate context of these two situations. The study sites also aimed to reflect a broad range in contexts in terms of distance and access to urban areas and agroecological conditions. In this respect, the communities of Ecuador were generally located much closer and with better access to urban areas compared to the other two sites. Meanwhile, the communities in Peru tended to be located at much higher elevations, and the communities in Bolivia were located at lower elevations.

We note that the surveys were undertaken in communities in which NGOs were active and not actively selected for the specific goals of this study. As such it is important to acknowledge potential sources of bias associated with site selection or NGO impact when interpreting the results and conclusions of the research.

Given that the household surveys were developed to address specific objectives of already existing projects, sampling methodology varied among study sites accordingly. In Bolivia and Peru, sampling was undertaken using randomized sampling techniques of households based on lists of households in each community. In Ecuador on the other hand, a geographically stratified sampling strategy was used, based on grid locations developed using GIS software across the project area. The farming household located at the center of each of the geographical grid points were requested to participate in the survey. In the cases that the household refused to participate a neighboring household was asked instead.

While measurement errors are often a common limitation in household surveys (Fraval et al., 2020), these were minimized by using electronic data collection techniques that had been trialed in the study sites before commencing the surveys. Moreover, the rural household survey administered (RHoMIS) has now been trialed in more than 33 countries and has therefore undergone a number of adaptations to ensure as few measurement errors as possible through a survey validation process built in to the survey (van Wijk et al., 2020). The survey has also been designed to be as rapid as possible to avoid fatigue of the individuals answering on behalf of the households (average time 40–60 min) (Hammond et al., 2017).

Data Analysis

To create the livelihood strategy household typology Ward's method of hierarchical clustering (Ward, 1963) was applied to the data of households that either: (1) incorporated off-farm income into their livelihood strategy, or (2) did not incorporate off-farm income into their livelihood strategy. The variables included in the clustering analysis included farm production variables, and the off-farm income activities variables for those

TABLE 1 | Description of variables collected by the RHoMIS survey used to assess the associations between household characteristics, farm production, and farming management collected in rural Andean communities in three South American countries.

Variable (unit)	Variable type	Description
HOUSEHOLD CHARACTERISTICS		
Age of female household head (years)	Continuous	Mean age of the female head
Age of male household head (years)	Continuous	Mean age of the male head
Age of household head(s) (years)	Continuous	Mean age of the head(s) of household combined
Household size (number of persons)	Continuous	Size of household
Household labor availability (number of persons above 10 years old)	Continuous	Size of household minus children aged 10 and under
Education level (highest education level of the head(s) of household)	Ordinal	0 = no education; 1 = primary education; 2 = secondary education; and 3 = post-secondary education
Household head composition (single or couple)	Binary	Single household head (0); two heads of household or couple (1)
OFF-FARM ACTIVITIES		
Off-farm income count (members of household engaged in off-farm activities)[#]	Continuous	Number of household members engaged in off-farm income activities
Off-farm income proportion (%)[#]	Continuous	Estimation of proportion of total household income from off-farm income activities
Participation in high value off-farm income (highest value level of off-farm income activities)[†#]	Ordinal	No off-farm employment activities (0); only very basic menial off-farm employment such as local farm laborer (1); salaried off-farm employment or skilled labor employment (e.g., governmental employee, maid, transport, shop keeper) (2)
FARM PRODUCTION		
Farm income (US$ $year^{-1}$)[#]	Continuous	Total amount of cash generated by farm sales (based on reported annual production and sales of crops and livestock)
Cropping market orientation (proportion of crops sold)[#]	Continuous	Proportion of annual crops produced that are sold to market
Crop sales (US$ $year^{-1}$)	Continuous	Income generated from crop sales
Crop value ha (US$ $year^{-1}$ ha^{-1})	Continuous	Crop production expressed in US$ a year per ha per farm
Land cultivated (ha)[#]	Continuous	Amount of land available for the farming household to cultivate
Value crop produce (US$ $year^{-1}$)[#]	Continuous	Crop production expressed in US$ a year per farm
Livestock market orientation (proportion of livestock sold)[#]	Continuous	Proportion of annual livestock products that are sold to market
Livestock product sales (US$ $year^{-1}$)	Continuous	Income generated from sales of livestock and livestock products
Value livestock production (US$ $year^{-1}$)[#]	Continuous	Livestock production expressed in US$ a year per farm
Livestock holdings (TLU)[#]	Continuous	Total livestock holdings (all farm animals)
FARM MANAGEMENT		
Mechanized tillage (usage)	Binary	No reported use of mechanized tillage (0); reported use of mechanized tillage (1)
N fertilizer inputs (kg N $year^{-1}$ ha^{-1})	Continuous	Reported amount of nitrogen applied on farm through chemical fertilizers
Pesticide use (usage)	Binary	No reported use of pesticides (0); reported use of pesticides (1)
Agroforestry (proportion of farming households)	Binary	No reported use of agroforestry (0); reported use of agroforestry (1)
Manure inputs (usage)	Binary	No reported use of manure (0); reported use of manure (1)
Crop rotation (usage)	Binary	No reported use of crop rotation (0); reported use of crop rotation (1)
Legume rotation to enhance soil fertility (usage)	Binary	No reported use of legumes (0); reported use of legumes (1)
Crop diversity (count)	Continuous	Number of crop varieties cultivated
Livestock diversity (count)	Continuous	Number of livestock species kept

[†] *See Appendix 1—**Supplementary Table 1** for an overview of the higher value income employment observed in the surveys.*
[#] *Variables input into BCA for development of livelihood household typology.*

households incorporating off-farm income into their livelihood strategies (**Table 1**). Due to strong correlations between some of the crop production (crop sales, crop value ha, and value crop produce) and livestock production variables (livestock product sales, value livestock production), crop sales, crop value per hectare, and livestock product sales were removed from the analysis. Using clustering tree diagrams, the number of household livelihood strategy types created for farm-focused household livelihoods (not incorporating off-farm income) was four. For households incorporating off-farm income, three household types were created.

To further visualize and test for differences among livelihood strategy types, a between class principal component analysis (PCA) was applied to each of the sets of household typologies (farm-focused households and with off-farm income) using the same variables as the cluster analysis. A Monte Carlo between

TABLE 2 | Number of rural household livelihood strategy types by country (followed by percentage in parenthesis).

	Household type						
	Farm-focused (FF)				Off-farm income (OF)		
Location	FF 1—livestock specialists	FF 2—commercial farms	FF 3—crop specialists	FF 4—subsistence	OF 1—mixed livelihoods	OF 2—mixed livestock specialists	OF 3—stepping-out
All sites	157 (27%)	69 (12%)	112 (20%)	68 (12%)	100 (17%)	39 (6%)	43 (7%)
Bolivia	19 (14%)	53 (40%)	1 (<1%)	55 (41%)	5 (4%)	1 (<1%)	0 (0%)
Ecuador	97 (35%)	15 (5%)	56 (20%)	45 (16%)	15 (5%)	25 (9%)	28 (10%)
Peru	41 (24%)	1 (<1%)	55 (32%)	23 (14%)	27 (16%)	9 (5%)	14 (8%)

class PCA test was also applied to assess for significant differences among household livelihood strategy types.

Individual mixed error component models were then applied, including "country" as a fixed effect and nested random effects for "region" and "municipality" in order to account for location-specific effects, to assess differences among livelihood strategy types in terms of farm production, off-farm income activities, household characteristics, and farm management variables. Fisher's least significant difference tests were applied to examine the differences among livelihood strategies, such that livelihoods with different letters were found to have different estimated marginal means at the 5% significance level.

Assumptions of homoscedasticity and normality were tested for all continuous variables and data transformed as needed using the log function. All analyses were carried out within the RStudio environment version 1.2.1335 for R (version 3.6.1) using ade4, agricolae, lmerTest and emmeans packages.

RESULTS

Livelihood Strategy Typology Development and Characterization

The hierarchical clustering identified three livelihood strategy types incorporating off-farm income (OF1, OF2, OF3), and four livelihood strategy types that did not incorporate off-farm income, or farm-focused livelihood strategies (FF1, FF2, FF3, FF4). The number of households falling in each livelihood strategy ranged from 39 households in OF2 to 157 households in FF1. While generally there was a fairly proportional distribution of the livelihood strategy types in the rural communities in Ecuador and Peru with the exception of FF2 in Peru which only had one household, in Bolivia household livelihood strategies were dominated by FF2 and FF4 livelihood strategies (**Table 2**).

The between class PCA confirmed significant differences among livelihood strategy types (Monte Carlo test based on 999 replicates, $p = 0.001$). For the livelihood strategy types incorporating off-farm income, Principal Component 1 (PC1) accounted for 35% of variance, while Principal Component 2 (PC2) accounted for 18% of variance. OF1 and OF3 livelihood strategies differed primarily along PC1. While OF1 was more positively correlated with variables associated with farm production such as value crop production, land cultivated, farm income, livestock holdings, and crop market orientation, OF 3 correlated positively with proportion of off-farm income and value of off-farm activities. OF2 differed to OF1 and OF3 along PC2. OF2 livelihood strategies correlated most strongly with livestock market orientation. Proportion of off-farm income, value of off-farm activities, off-farm incomes count, and livestock value production also positively correlated with OF2 (**Figure 3A**).

For farm focused livelihood strategy types, PC1 accounted for the greatest variance among livelihood strategy types (73%), while PC2 accounted for 23% of variance. FF1 and FF2 differed from FF3 and FF4 primarily along PC1. Both FF1 and FF2 correlated more with all the farm production variables (crop market orientation, livestock holdings, livestock market orientation, livestock value production, farm income, land cultivated, and crop value production). FF1 differed to FF2 along PC2. FF1 correlated more with livestock market orientation and value livestock production, while FF2 correlated more with value crop production, land cultivated, and farm income (**Figure 3B**).

The mixed error component model analyses showed that the FF2 household livelihood strategy type displayed the highest levels in nearly all the farm production variables analyzed (farm income, crop market orientation, crop sales, crops value, land cultivated, value of crop produce, value of livestock production, and livestock holdings). The only variable in which it did not display the highest levels was livestock market orientation. Given these results, one could characterize these households as "commercial farms." The livelihood strategy that displayed the lowest in nearly all the farm production variables was FF4. The only two variables where FF4 did not display the lowest levels was for crop value per ha and livestock market orientation, although for both of these variables the levels were not statistically different from the types with the lowest levels. These farming households could therefore be interpreted as "subsistence" farming households. The differences between FF1 and FF3 appeared to be borne out in their differences in whether their focus was orientated toward livestock or agricultural crop production. FF3 households in particular displayed among the lowest levels of livestock production suggesting that they were more oriented toward agricultural crop production ("crop specialists"). FF1 households on the other hand displayed among

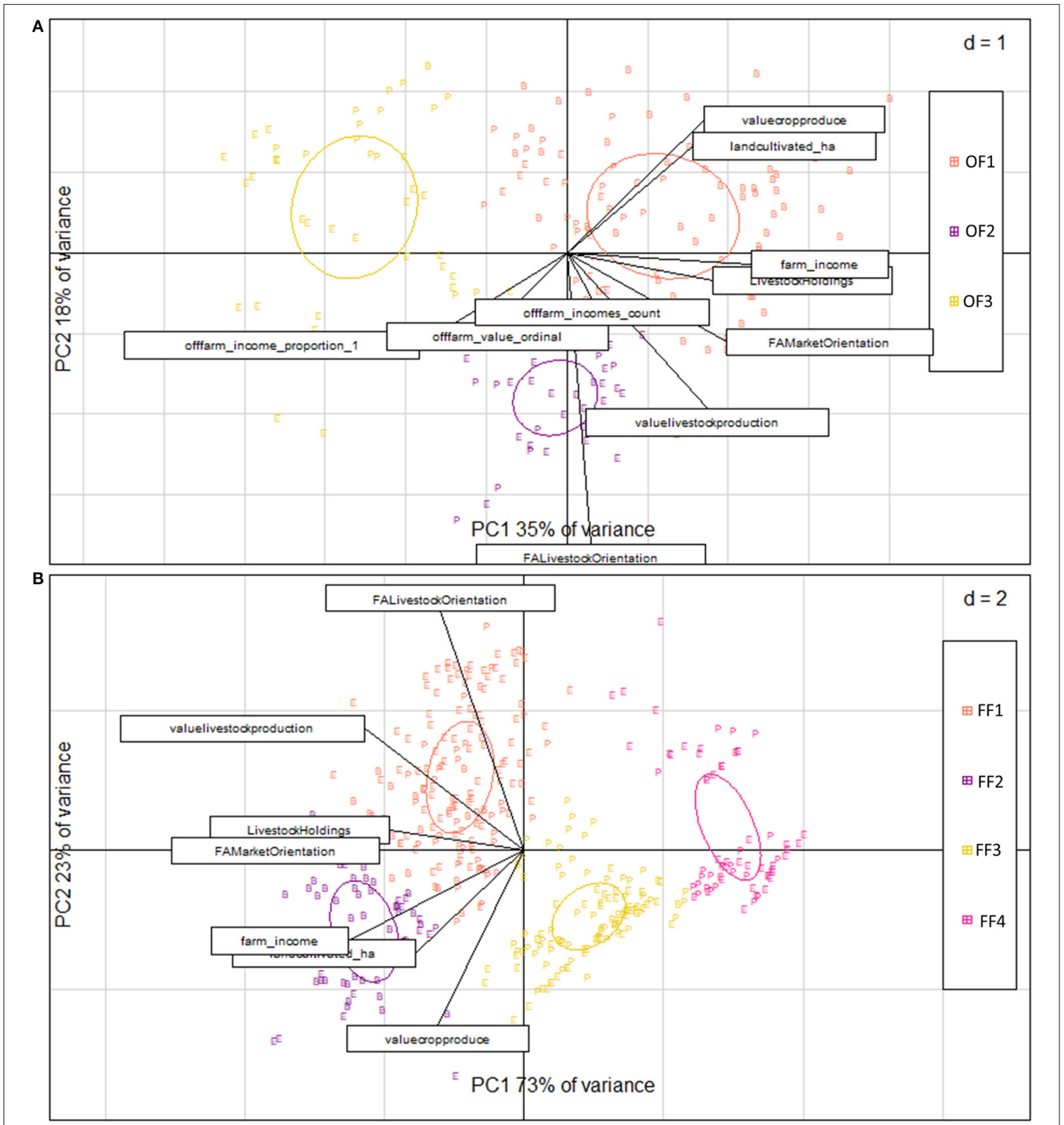

FIGURE 3 | Between class principal component analysis assessing correlations between farm production and household livelihood strategy types. **(A)** Livelihood strategies that incorporated off-farm income. **(B)** Farm-focused livelihood strategies. Letters correspond to country location of household (B = Bolivia, E = Ecuador, P = Peru). Ellipses correspond to livelihood strategy defined by hierarchical clustering (**Table 2**).

the highest levels for most livestock production variables and therefore could be viewed as "livestock specialists" (**Table 3**).

Among the households with off-farm income incorporated into their livelihood strategies, OF1 households generally displayed the highest levels of farm production variables for agricultural crop production, and relatively high levels of livestock production. For the off-farm livelihood variables, OF1 exhibited the smallest proportion of off-farm income and the

TABLE 3 | Estimated marginal means for farm production variables of the different household livelihood strategy types[#].

Variable	FF1—livestock specialists	FF2—commercial farms	FF3—crop specialists	FF4—subsistence	OF1—mixed livelihoods	OF2—mixed livestock specialists	OF3—stepping-out
Farm income	809 (193)d	5,988 (3,230)e	254 (68)c	<1 (<1)a	1,282 (368)d	394 (139)c	3 (1)b
Crop market orientation	0.7 (0.03)d	0.85 (0.04)e	0.5 (0.04)c	0.0 (0.04)a	0.72 (0.04)d	0.64 (0.05)d	0.19 (0.05)b
Crop sales	28 (9)c	6,311 (3,667)f	161 (61)d	<1 (<1)a	904 (353)e	5 (3)b	1 (1)b
Crop value ha	327 (68)ab	868 (264)c	392 (88)ab	278 (78)ab	461 (107)b	227 (72)a	343 (106)ab
Land cultivated	2.5 (0.3)b	4.9 (0.8)d	2.4 (0.3)b	1.2 (0.2)a	3.3 (0.4)c	1.5 (0.3)a	1.2 (0.2)a
Value crop produce	774 (100)c	3,316 (1,042)e	869 (127)c	229 (44)a	1,433 (227)d	330 (71)ab	386 (83)b
Livestock market orientation	0.51 (0.02)d	0.12 (0.03)bc	0.01 (0.03)a	0.06 (0.04)ab	0.17 (0.03)c	0.63 (0.04)e	0.07 (0.04)abc
Livestock product sales	756 (152)b	1,586 (186)c	98 (162)a	62 (178)a	543 (163)b	702 (198)b	42 (196)a
Value livestock production	478 (123)c	405 (150)c	<1 (<1)a	<1 (<1)a	61 (18)b	536 (227)c	<1 (<1)a
Livestock holdings	4.30 (0.5)c	6.32 (0.91)d	2.26 (0.3)b	1.24 (0.21)a	3.79 (0.44)c	3.39 (0.54)c	1.57 (0.29)ab

[#]*Standard errors are presented in parentheses and results from Fisher's least significant difference test are indicated by lower case letters next to standard errors, such that livelihoods with different letters have different estimated marginal means at the 5% significance level. See* ***Table 1*** *for description of variables and units.*

second lowest number of household members participating in off-farm livelihood activities. OF1 households also had the lowest value of off-farm activities, indicating that the off-farm activities that these households engaged in tended to be more basic menial labor (i.e., at a local farm or unskilled construction). These households could be said to have "mixed livelihoods." OF2 households on the other hand displayed among the highest levels of livestock production for value of livestock production, livestock market orientation, and livestock product sales. Livestock holdings were also comparable to OF1 and FF1, the farm-focused livestock specialists. For the off-farm livelihood variables OF2 exhibited the highest number of members of household undertaking off-farm livelihood activities. These households also displayed among the highest value in their off-farm activities, meaning that they were more likely to be work as a governmental employee, driver, shop-keeper, etc. (see **Supplementary Table 1** for an overview of off-farm activities that were considered to be higher-value). As such, these households were coined "mixed livestock specialists." Finally, OF3 households displayed often similarly low levels in the farm production variables as FF4, the subsistence households. However, for the off-farm livelihood variables these households displayed the highest proportion of off-farm income. They also had the joint highest value for their off-farm income activities (along with OF2) meaning that the off-farm income activities were more likely to be work such as a governmental employee, driver, shop-keeper (as indicated in **Supplementary Table 1**). It is noteworthy that these households displayed the fewest members of the household participating in off-farm activities. Given the low farm production levels and the highest proportion of off-farm income, the livelihood strategy for these households could be perceived as "stepping-out" of farming (**Tables 3**, **4**).

TABLE 4 | Estimated marginal means for off-farm income activity variables of the different household livelihood strategy types incorporating off-farm income activities[#].

	Livelihood strategy type		
Variable	OF1—mixed livelihoods	OF2—mixed LS specialists	OF3—stepping-out
Off-farm income count (number of members of household engaged in off-farm activities)	1.1 (0.02)b	1.2 (0.03)c	1.0 (0.03)a
Off-farm income proportion	0.3 (0.02)a	0.5 (0.02)b	0.6 (0.02)c
Participation in high value off-farm income	1.2 (0.05)a	1.5 (0.06)b	1.5 (0.06)b

[#]*Standard errors are presented in parentheses and results from Fisher's least significant difference test are indicated by lower case letters next to standard errors, such that livelihoods with different letters have different estimated marginal means at the 5% significance level. See* ***Table 1*** *for description of variables and units.*

Household Characteristics and Livelihood Strategy Types

The subsistence livelihood strategy household type had the oldest household heads, 58 years, while the stepping-out livelihood strategy household type had the youngest household heads, being on average 15 years younger (43 years). Similarly, for education level of household heads the biggest difference between livelihood strategy types was found between stepping-out livelihood strategy households, having the highest average education level (at least 30% having completed primary education), and subsistence livelihood strategy households, who had the lowest education level attainment with only 7% completing primary school. Subsistence households also comprised the highest number of single household heads, while the household livelihood strategy types that incorporated off-farm income generally had most household heads that were a couple. Livestock specialists, crop specialists, and mixed livelihood households were the smallest households (3.91, 3.77, and 3.94 persons, respectively), while mixed livestock specialists were the largest (4.81 persons).

Livelihood Strategies and Farm Management Techniques

Farm management variables associated with more industrialized approaches to farming such as mechanized tillage, and the use of chemical fertilizers and pesticides were used more by farm focused livestock specialists, commercial farms, and crop specialists households, and by mixed livelihood households. Notably, mixed livelihood households applied nearly 60% more chemical fertilizers than any other household livelihood strategy type; they were also the second most likely to use pesticides and mechanized tillage, slightly less than the commercial farming households. Subsistence and stepping-out livelihood strategy types on the other hand consistently were the least likely households to employ these types of farming practices (**Table 6**). In relation to agroecological techniques for agricultural intensification, while the commercial farms were the most likely to employ agroforestry practices, they were also the least likely to use manure inputs, crop rotation, or the rotational planting of legume crops to enhance productivity. Subsistence households were the most likely to use manure inputs, while mixed livestock specialists were the most likely to rotate crops and use legume crops as part of the rotation. Crop diversity tended to be highest in the farm-focused livestock specialists, commercial farms, and crop specialists households, and by mixed livelihood households. It was lowest for subsistence household types, which also had the lowest levels of livestock diversity, while mixed livestock specialists tended to have the greatest livestock diversity (**Table 6**).

DISCUSSION

Off-Farm Income, Livelihood Diversification, and Farm Management

Households in these rural Andean contexts have developed distinct livelihood strategies that are associated with significantly different approaches to farm production and management. Among farm households without any off-farm income, four livelihood strategy types emerged: commercial farms, livestock specialists, crop specialists, and subsistence farms. Among households that derived part of their income from off-farm sources three main livelihood strategy approaches emerged: one that remained focused on commercial farm production activities and that generated significant amounts of off-farm income in parallel (mixed livelihoods); another household type that mixed their off-farm livelihood activities with an on-farm specialization in livestock production (mixed livestock specialists); and a third type that appeared to be stepping-out of farming activities, generating the majority of income from off-farm sources and dedicating most farming activities to self-consumption (stepping-out).

One of the striking findings from this study was that households that incorporated off-farm income exhibited a similar diversity in terms of livelihood strategies among households as those that did not incorporate off-farm income (**Figure 3**; **Tables 3**, **4**). Moreover, this diversity in livelihood strategies among households incorporating off-farm income was also associated with significant differences in terms of farm management. Specifically, our findings revealed that among farming households that generated off-farm income, mixed livelihood household types displayed the greatest use of industrialized farming techniques (**Table 6**). These households also applied 60% more chemical fertilizers than any household types focused on farm production as their sole source of income. Overall, they were also the second most likely household type to use pesticides and mechanized tillage, slightly less than the farm-focused commercial farms. In terms of farm production, mixed livelihood types also exhibited among the highest levels of market orientation and value production (**Table 3**), often having the second highest levels for these variables, only just a little less than commercial farm households, but higher than the other farm-focused household types. These findings suggest that mixed livelihoods households may be opting to invest some of their financial resources gained from off-farm income in industrialized farming techniques. This reflects the findings of others who have reported a positive correlation between off-farm income and the use of more industrialized farming techniques (Gray and Bilsborrow, 2014; Bhandari and Ghimire, 2016; Caulfield et al., 2019).

Furthermore, out of the household livelihood strategies that generated off-farm income, mixed household types generated less of their overall income from off-farm activities (30%) compared to mixed livestock specialists (50%) and stepping-out households (60%). The type of off-farm activity undertaken by mixed livelihood households was also more likely to be menial labor (i.e., farm hand or unskilled construction worker; **Table 4**). This further supports the idea that these households may be simply using off-farm activities to generate more financial resources in order to re-invest in their farming activities.

At the other end of the spectrum, stepping-out households generally displayed significantly lower levels for farm production and industrialized farming techniques variables, not dissimilar to farm-focused "subsistence" households (**Tables 3**, **6**), confirming the idea that farm production was only a supplemental activity aimed at meeting a self-consumption objective. In this respect our findings corroborate the work of other authors who suggest an association between off-farm income and farming deintensification (e.g., Jokisch, 2002; Benayas et al., 2007). It is likely that in contexts where the income generated from off-farm sources is sufficient and of high enough value, there is a lower dependency on agriculture and local natural resources for livelihoods and therefore a trend toward farming deintensification (Qin, 2010).

This relationship between high value off-farm income generation and farm deintensification is further supported by the fact that while stepping-out households generated the greatest proportion of off-farm income of their total income (60%), the average number of household members engaged in off-farm activities, was lowest among the three livelihood strategy types that undertook off-farm activities (**Table 4**). This suggests that the income generated by their off-farm activities was disproportionally higher per household member engaged in off-farm activities despite the fact that mixed livelihood specialists exhibited the same levels of participation in high-value off-farm

income activities, enabling them to rely less on on-farm income. Unfortunately, further detail related to off-farm income activities were not available from the household surveys to be able to assess these relationships in greater depth. Further research on the relationships between farm production and management, and the nature and value production of off-farm income activities is therefore highly recommended.

Finally, off-farm livestock specialists represented a household type that appeared to mix significant amounts of off-farm activity with a specialization in livestock production, displaying similar levels of farm production as the farm-focused livestock specialist households, and with similarly low levels of agricultural inputs whether industrial or more agroecological (**Tables 4**, **6**). Again, this relationship between off-farm income generation and farm production and management is reflected in the scientific literature. For example, in a study undertaken in Bukina Faso, larger amounts of off-farm income from international remittances stimulated livestock production (Wouterse and Taylor, 2008).

These results provide a potential explanation for the often contrasting findings on the effects of off-farm income on farm management, where off-farm income has led to different scenarios at the farm level such as an increased use in industrialized farming techniques or an overall deintensification of farming activities (Jokisch, 2002; Gray and Bilsborrow, 2014; Tegegne and Penker, 2016). Specifically, as opposed to the linear relationships between off-farm income and farm management often presented in the scientific literature, here we observe the emergence of three different approaches to farming associated to different livelihood strategy types.

As hypothesized (**Figure 1**), when comparing these three household livelihood strategies, we cannot conclude that the generation of off-farm income is linearly associated with deintensification of farming activities and consequent re-establishment of non-agricultural land uses. This might be expected due to the potential decrease in access to labor resources, posited by the Forest Transition Theory (Rudel et al., 2005). In fact, as hypothesized by the theory of New Economics of Labor Migration, off-farm income generation can have a countervailing effect on the loss of labor resources (Taylor, 1999). Increases in financial resources from off-farm income are often positively associated with the use of industrialized agricultural inputs such as mechanized tillage, chemical fertilizers and pesticides (Davis and Lopez-Carr, 2010; Greiner and Sakdapolrak, 2013; Gray and Bilsborrow, 2014), and have even been used to address labor constraints through the hiring of extra labor from neighbors or local migrants (Zimmerer, 2014).

These differences between household livelihood strategies that generate off-farm income is an important finding, as it suggests that not only is the association between off-farm income and farm management non-linear, but that enhanced rural mobility and access to off-farm income opportunities enables further livelihood diversification. In fact, it appears that the generation of off-farm income can provide for diversified forms of livelihood strategies that enable rural households to "remain" (Zoomers, 2012; Mata-Codesal, 2018; Ye, 2018). However, it is important to point out, as argued in Caulfield et al. (2019) and Zimmerer and Vanek (2016), shifts in livelihood diversification pathways that involve the use of more industrialized forms of farming could pose long-term challenges to the sustainability of farming in these rural Andean landscapes due to land degradation.

Livelihood Strategies, Rural Household Characteristics, and Context Dependency

It is striking that stepping-out households represented the youngest and most educated households among all seven livelihood strategy types (**Table 5**). This is an important finding that corroborates the reports from inhabitants across the communities studied here, suggesting that the young are stepping-out of farming both permanently, through permanent out-migration, and economically, as those young households that remain tend to be deintensifying their farming activities. These results also reflect other studies that suggest that household characteristics are associated with different livelihood strategies (Carr, 2014; Dodd et al., 2016; Lopez-Carr et al., 2017).

TABLE 5 | Estimated marginal means for household characteristics of the different household livelihood strategy types[#].

Variable	Livelihood strategy type						
	FF1—LS specialists	FF2—commercial farms	FF3—crop specialists	FF4—subsistence	OF1—mixed livelihoods	OF2—mixed LS specialists	OF3—stepping-out
Age female head	51.3 (1.4)bc	44.0 (2.1)a	52.7 (1.6)cd	56.1 (2.0)d	47.3 (1.6)ab	48.0 (2.4)abc	42.9 (2.4)a
Age male head	54.3 (1.5)c	45.0 (2.1)a	55.0 (1.8)cd	59.7 (2.2)d	50.0 (1.7)b	45.9 (2.5)ab	43.8 (2.5)a
Age HH head	52.8 (1.4)c	44.7 (2.1)ab	54.0 (1.6)cd	57.7 (1.9)d	48.6 (1.6)b	46.9 (2.4)ab	42.8 (2.4)a
Education ordinal	0.9 (0.06)ab	1.2 (0.09)cd	0.9 (0.07)a	0.7 (0.09)a	1.1 (0.07)c	1.1 (0.10)bc	1.4 (0.10)d
HH size	3.9 (0.2)a	4.6 (0.3)ab	3.8 (0.3)a	4.0 (0.3)ab	3.9 (0.3)a	4.8 (0.4)b	4.1 (0.4)ab
HH head composition (proportion couple)	0.76 (0.04)ab	0.89 (0.04)cd	0.77 (0.05)abc	0.67 (0.07)a	0.92 (0.03)d	0.94 (0.04)d	0.89 (0.05)bcd

[#]*Standard errors are presented in parentheses and results from Fisher's least significant difference test are indicated by lower case letters next to standard errors, such that livelihoods with different letters have different estimated marginal means at the 5% significance level. See* ***Table 1*** *for description of variables and units.*

Education in particular appears to be playing an important role in enabling younger households to engage in higher value off-farm income. It is likely that there is an important link between average age of heads of household, education level, and the participation in high-value off-farm income activities (Tegegne and Penker, 2016). In this respect, younger households in rural communities in the Andes may be taking advantage of the opportunities presented by their improved education levels and enhanced access to high-value off-farm income sources. As they do so they may also be building networks that decrease their vulnerability in the face of important socio-environmental challenges, such as climate change and poverty (Zoomers, 2012).

At the other end of the spectrum, it is also noteworthy that households with subsistence livelihood strategies tended to be older and less educated than the other households. Furthermore, reflecting the findings of Carr (2014), these rural households also exhibited a higher proportion of single heads of household (**Table 3**). These findings potentially indicate the greater vulnerability of these households due to their lower human capital and therefore lower capacity to adapt their livelihood strategies in the face of changing socio-environmental conditions (Reza Shahraki et al., 2017; Shikuku et al., 2017; Odhiambo et al., 2019). We also need to consider the possibility that stepping-out and subsistence household types represent instances in a rural household's lifecycle, where household livelihood strategies evolve over a household's family lifecycle in order to adapt to different opportunities and challenges related to changes to human capital. This idea fits with the rural Household Lifecycle Theory (Perz and Walker, 2002; Walker et al., 2002); however, without more longitudinal data for our study this possibility is difficult to verify.

In contrast to the significant differences observed for stepping-out and subsistence households, it is notable that there was less variation in household characteristics among the other household types (**Table 5**). This suggests that between the higher and lower ends of the spectrum for household characteristics, livelihood diversification may be being driven by the influence of other factors. As concluded by a study in the Andean valleys of Bolivia, structural factors are also likely to be highly influential in terms of which pathways farming households employ as livelihood strategies (le Grand and Zoomers, 2017). Indeed, as argued by Black et al. (2011), environmental, political, demographic, social, and economic factors are all likely to mediate household level decisions with regard to how and whether to incorporate off-farm income opportunities presented by enhanced rural mobility into livelihood strategies.

In the current study these structural effects on livelihood diversification may be borne out in a number of ways. For example, the Ecuadorian research site was characterized by the highest proportion of households with a stepping-out livelihood strategy (**Table 2**), despite the households in this country's survey registering older heads of household on average (54.1 years compared to 48.1 and 48.6 in Peru and Bolivia, respectively). Part of the reason for this finding may be related to the fact that the Ecuadorian rural households may have had better access to off-farm employment, as transport links and distances to economic centers was relatively favorable compared to the other countries. On the other hand, in Peru there were proportionally fewer commercial farm households and more subsistence households. This could have been a result of the fact that the location of the research site results in more households that were at very high elevations with significant challenges in terms of access to markets and irrigation water. Finally, in Bolivia, very few households were observed to incorporate off-farm income generating activities within their livelihood strategies. Indeed, no household in Bolivia was observed to be "stepping-out" of farming. Part of the reason for this is likely due to the fact that farming in the communities in Bolivia from this study was much more profitable than farming in the communities from Ecuador or Peru. According to our data, on average farming households from Bolivia generated over twice as much income from farm production ($3,000) than Ecuador ($1,190), and over four-fold more than Peru ($692).

As such, our findings suggest that while household level characteristics may have an important role to play in influencing the livelihood strategies households employ, these variables should not be perceived as deterministic, such that "younger" households will always employ commercial or stepping-out livelihood strategies. Instead, we argue that the potential influences of different household characteristics on livelihood strategies will also vary from location to location and household to household. This conclusion reflects other studies who have found important location-specific influences on the incorporation of rural mobility opportunities within the overall livelihood strategies of households (de Sherbinin et al., 2008; Radel et al., 2019). For example, in a study from Ethiopia, while a number of different household characteristics, such as age and education of household heads, were observed to have important influences on whether members of a household would incorporate off-farm income activities within their livelihood strategies, location was also a strong determinant (Tegegne and Penker, 2016).

Further research is recommended to explore how different household characteristics may be interrelated, how these patterns may change over a farming household lifecycle, as well as their relationship with other macro-scale variables, in order to build a better appreciation of the pathways which influence the adoption of different livelihoods and to guide future and more nuanced intervention strategies.

Policy Implications

Our findings suggest that rural development programmes and projects need to explicitly recognize this diversity in household livelihood strategies for more effective engagement and innovations with rural farming communities. For example, interventions aimed at commercial farm or mixed livelihood households are unlikely to be effective for subsistence or stepping-out livelihood strategy households. Not only are farming priorities likely to be different, but inherent opportunities for and barriers to more sustainable change are likely to differ for the different household types, and by context and location (Ruben and Pender, 2004). As we have seen in

the results from this study and others, while the generation of high-value off farm income may be an option for livelihood diversification and therefore resilience-building for the younger more educated rural households, this may not be an option for other rural households. Without more nuanced approaches to development, that integrate these differences, rural development programmes, and policy is unlikely to be any more successful in the future (Descheemaeker et al., 2016). A concrete example of how this may be done was recently trialed in a project in Rwanda, where the use of household typologies enabled the characterization of the different populations into discrete groups in order to prioritize farm types for engagement, and locations for further investment (Hammond et al., 2020).

Moreover, given the large proportion of mixed livelihoods and commercial farms in the Andean communities studied here and their greater reliance on farming techniques that are associated with land degradation, such as the use of agrochemicals and mechanized tillage (Fonte et al., 2012), these groups of farming households could be viewed as high-leverage "audiences." Engagement with these household types on more sustainable agroecological intensification techniques is critical to transform overall landscape level agroecosystem performance. This is only likely achievable through a better understanding of their context and motivators. The fact that large proportions of households still practiced agroecological techniques (**Table 6**), even within farming households that employed more industrialized approaches to farming, indicates a promising entry point for engagement on agroecological intensification. To this extent it will be important to engage in the already lively debate in these rural communities around the desirability of agroecological and industrialized approaches to farming, recognizing that choices are driven by local norms and conversations.

CONCLUSION

Household livelihood strategies that incorporate off-farm income through the opportunities presented by rural mobility are associated with different approaches to farm management. Our findings suggest that this relationship does not boil down to a direct linear relationship between off-farm diversification and farm management. Instead enhanced rural mobility and access to off-farm income opportunities appears to facilitate greater livelihood diversification with intricate links with farm management approaches enabling rural households to "remain." Another important finding in this study is that household characteristics played an important role in influencing rural households' livelihood strategy. Age and education, in particular, appear to be variables that influence the ability of households to integrate higher value off-farm income activities into their livelihoods. However, we argue that these variables should not be perceived as deterministic. Indeed, despite similar household characteristics a number of livelihood strategy types exhibited important differences in their approach to farm production and management. In these cases, other, location-specific, contextual factors are likely to be highly influential in terms of which pathways farming household choose as livelihood strategies. From a policy perspective this research provides important insights for improved rural development. In particular, the relationships between household characteristics, livelihood strategies and farm management underline the argument that drivers for more or less sustainable land management will vary location to location and household to household. Programmes and projects must therefore take into account this heterogeneity and engage in the already advanced conversations around different approaches to farming and the conservation of common natural resources.

TABLE 6 | Estimated marginal means for farm management practices of the different household livelihood strategy types[#].

Farming management/technique		Livelihood strategy type						
		FF1—LS specialists	FF2—commercial farms	FF3—crop specialists	FF4—subsistence	OF1—mixed livelihoods	OF2—mixed LS specialists	OF3—stepping-out
Industrialized farming techniques	Mechanized tillage	0.49 (0.12)b	0.60 (0.15)b	0.46 (0.13)b	0.20 (0.09)a	0.53 (0.13)b	0.28 (0.13)ab	0.27 (0.12)ab
	N fertilizer inputs	2.58 (0.87)c	2.44 (1.32)c	2.11 (0.83)c	0.33 (0.19)a	4.07 (1.56)c	1.36 (0.77)bc	0.40 (0.24)ab
	Pesticides	0.58 (0.09)bc	0.87 (0.06)d	0.59 (0.10)bc	0.47 (0.11)ab	0.71 (0.08)c	0.42 (0.12)ab	0.33 (0.10)a
Agroecological farming techniques	Agroforestry	0.63 (0.07)ab	0.81 (0.09)b	0.61 (0.08)ab	0.55 (0.1)a	0.63 (0.09)ab	0.66 (0.1)ab	0.71 (0.09)ab
	Manure inputs	0.62 (0.15)bc	0.38 (0.17)a	0.58 (0.16)abc	0.72 (0.14)c	0.62 (0.16)abc	0.44 (0.18)ab	0.70 (0.15)bc
	Crop rotation	0.89 (0.18)a	0.86 (0.23)a	0.82 (0.28)a	0.90 (0.17)ab	0.89 (0.18)ab	0.95 (0.08)b	0.91 (0.15)ab
	Use legumes	0.89 (0.18)a	0.86 (0.23)a	0.82 (0.28)a	0.90 (0.17)ab	0.89 (0.18)ab	0.95 (0.08)b	0.91 (0.15)ab
Crop and livestock diversity	Crop diversity	2.84 (0.17)b	2.91 (0.23)b	2.88 (0.19)b	2.38 (0.18)a	3.01 (0.2)b	2.78 (0.24)ab	2.68 (0.23)ab
	Livestock diversity	2.25 (0.13)abc	2.4 (0.16)bc	2.06 (0.15)a	2.03 (0.17)a	2.24 (0.14)abc	2.42 (0.17)c	2.06 (0.18)ab

*Standard errors are presented in parentheses and results from Fisher's least significant difference test are indicated by lower case letters next to standard errors, such that livelihoods with different letters have different estimated marginal means at the 5% significance level. See **Table 1** for description of variables and units.*

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MC performed the statistical analysis and wrote the first draft of the manuscript. All authors contributed to conception and design of the study, data collection, manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.724492/full#supplementary-material

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