



# The agri-food system (re)configuration: the case study of an agroecological network in the Ecuadorian Andes

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## Abstract

Social Ecological System (SES) research highlights the importance of understanding the potential of collective actions, among other factors, when it comes to influencing the transformative (re)configuration of agri-food systems in response to global change. Such a response may result in different desired outcomes for those actors who promote collective action, one such outcome being food sovereignty. In this study, we used an SES framework to describe the configuration of local agri-food systems in Andean Ecuador in order to understand which components of the SES interact, and how they support outcomes linked to five food sovereignty goals. Through a survey administered to mestizo and indigenous peasants, we analyze the key role played by the Agroecological Network of Loja (RAL) in transforming the local agri-food system through the implementation of a Participatory Guarantee System (PGS). This study demonstrates that participation in the RAL and PGS increases farmers' adoption of agroecological practices, as well as their independence from non-traditional food. Additionally, RAL lobbying with the municipality significantly increases households' on-farm income through access to local markets. Being part of indigenous communities also influences the configuration of the food system, increasing the participation in community work and access to credit and markets, thus positively affecting animal numbers, dairy production and income diversification. The complexity of the interactions described suggests that more research is needed to understand which key factors may foster or prevent the achieving of food sovereignty goals and promote household adaptation amid high uncertainty due to global change.

**Keywords** Andes · Food sovereignty · Mestizo peasants · *Saraguro* · Indigenous people · Socio-ecological system

## Abbreviations

RAL Agroecological Network of Loja (in Spanish Red Agroecológica de Loja)  
PGS Participatory Guarantee System

LVC La Vía Campesina  
SES Socio-Ecological Systems  
RDA Redundancy Analysis  
A Actors  
GS Governance System  
RS Resource Systems  
RU Resource Units  
S Socio-Economic Drivers  
ECO Ecological Drivers  
I Interactions  
O Outcomes  
APUs Agricultural Production Units  
VIF Variance Inflation Factor  
AIC Akaike's Information Criterion  
INEC Instituto Nacional Estadística y Censos  
MAGAP Ministerio de Agricultura, Ganadería, Acuacultura y Pesca  
INPC Instituto Nacional del Patrimonio Cultural  
UNEP United Nations Environmental Program

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FAO	Food and Agriculture Organization of the United Nations
UN	United Nations
SINAGAP	Sistema Información Nacional Agricultura, Ganadería, Acuacultura y Pesca
INAMHI	Instituto Nacional de Meteorología e Hidrología

## Introduction

The conceptualization of agri-food systems as Social Ecological Systems (SES) is having a notable impact in agri-food research focused on sustainability (Ericksen 2008; Prospero et al. 2016; Marshall 2015) and involves the following aspects: developing new methodological frameworks that integrate the socio-economic, institutional and environmental dimensions of the agri-food system; analyzing the interactions that are taking place between the different components in production, transformation, commercialization and consumption activities; and understanding the potential outcomes resulting from such interactions. This conceptualization allows for agri-food to be studied as a dynamic system in its entirety and managed accordingly, with the associated critical feedback on temporal and practical scales (Thompson and Scoones 2009).

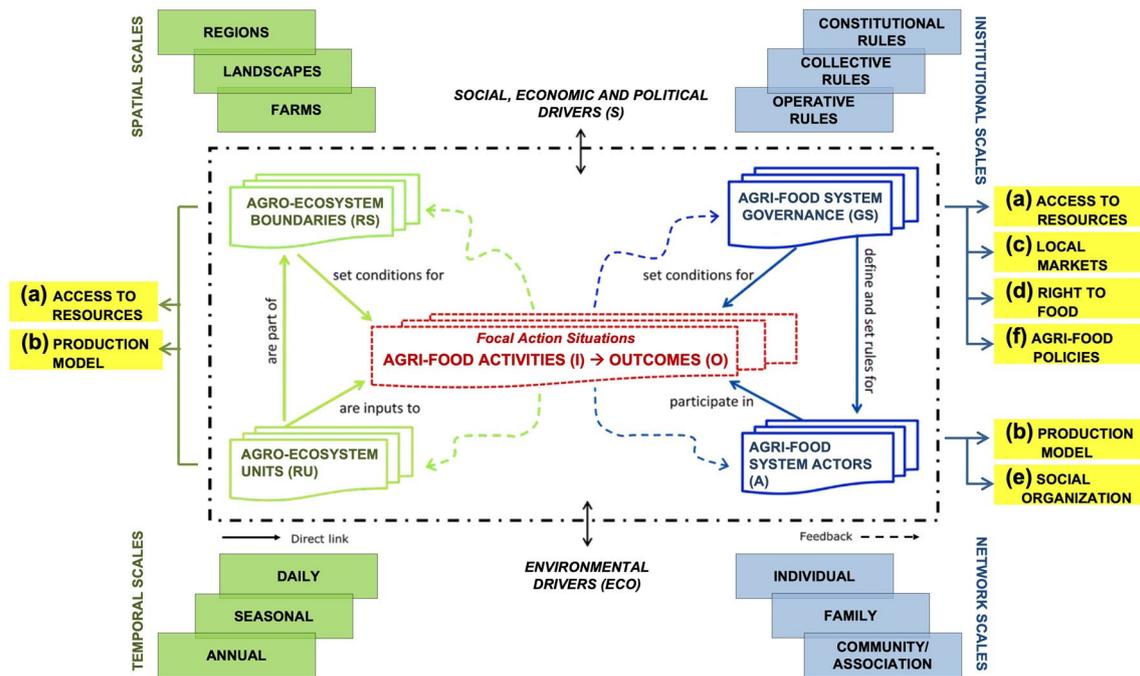
SES-based research highlights the importance of understanding the role played by collective action in influencing outcomes; that is, the transformative (re)configuration of agri-food systems in the face of multiple drivers of change. Collective action plays a key role in the management of complex SES, facilitating cross-level governance, the long-term protection of ecosystems and the well-being of different populations (Ostrom 1990; Brondizio et al 2009; Cox et al 2010; Ostrom and Cox 2010; Anderies and Janssen 2013). Specifically, the literature demonstrates that informal institutions, e.g. networks based on reciprocity and trust, may determine the level of success of collective action (Ostrom and Ahn 2003). Steins and Edwards (1999) studied how nested platforms (i.e. ones including different levels of decision-making) with different user groups may facilitate ecologically, economically, and socially-sustainable resource management by emphasizing social learning and collective action. In a case study of quinoa producers and short value chains in Bolivia Winkel et al. (2020) demonstrated that communing processes may facilitate social-economic inclusion and sustainability. Collective action has also been found to be essential in promoting food security (Pelletier et al. 1999).

Food sovereignty has been proposed as political proposal capable to transform agri-food systems towards sustainability and conceptualised into a set of pillars, categories and indicators to facilitate its analysis (Ruíz-Almeida and Rivera-Ferre 2019). Several studies have shown how diverse

and subaltern struggles -such as those based on collective action involving peasants, indigenous and women in many different contexts and aimed at promoting agroecology and food sovereignty- have the potential to transform agri-food systems (Martínez-Torres and Rosset 2014). Prior studies in the Peruvian Andean context have linked the role of barter markets -as an example of community-based collective action- to food sovereignty, mainly related to the promotion of social reciprocity and ecological diversity (Argumedo and Pimbert 2010). Some other studies have also demonstrated that the role of peasants and indigenous and other social movements in Ecuador has been pivotal in the push towards institutionalizing food sovereignty at the national level, both within the Constitution and policy design (Giunta 2014). In addition, research based on the sustainable rural livelihoods framework has emphasized the need to study the social and economic characteristics of context-specific agri-food systems, including market integration and income-generation strategies to support well-being and natural resource sustainability, and the capacity of rural communities and agri-food systems for transformative adaptation (Thompson and Scoones 2009).

SES-based research and food sovereignty studies are normally assessed independently. The aim of this article is to combine the two frameworks to understand how innovative collective action interacts and reorganizes the components of the local agri-food system, conceptualized as an SES, and has significant impacts on food sovereignty outcomes (Vallejo-Rojas, Ravera and Rivera-Ferré 2015). Additionally, the article explores whether other concurrent factors, such as being part of indigenous *comunidades* (i.e. the communal ancestral institutions) and having certain socio-economic characteristics, are also relevant in shaping agri-food systems. Our findings have multiple implications when it comes to policy design aimed at supporting adaptive transformations in the face of multiple drivers of change.

The framework is applied to a case study in the south Ecuadorian Andes. Our work was conducted with an informal agroecological innovative network of women *mestizo* and *Saraguro* indigenous peasants, the Agroecological network of Loja (*Red Agroecológica de Loja* in Spanish, hereafter RAL), which implements a Participatory Guarantee System (hereafter PGS). In studying this empirical case, the aims are to (1) select the most relevant variables that describe the local SES and its current configuration (i.e. architecture); (2) assess which key institutional and socio-economic factors explain a set of outcomes in terms of food sovereignty; and (3) discuss the key role of the RAL and other factors in transforming the local agri-food system towards food sovereignty. The conclusions highlight the implications of the findings with regard to future policy.



**Fig. 1** Methodological framework (adapted from McGinnis and Ostrom 2014). On the left, the ecological subsystems (RS and RU, green boxes), and on the right, the social subsystems (GS and A, blue boxes) with their respective scales and levels. For each subsystem, we

highlight the main links with food sovereignty pillars (yellow boxes). In the center, the agri-food activities and outcomes (red boxes). (Color figure online)

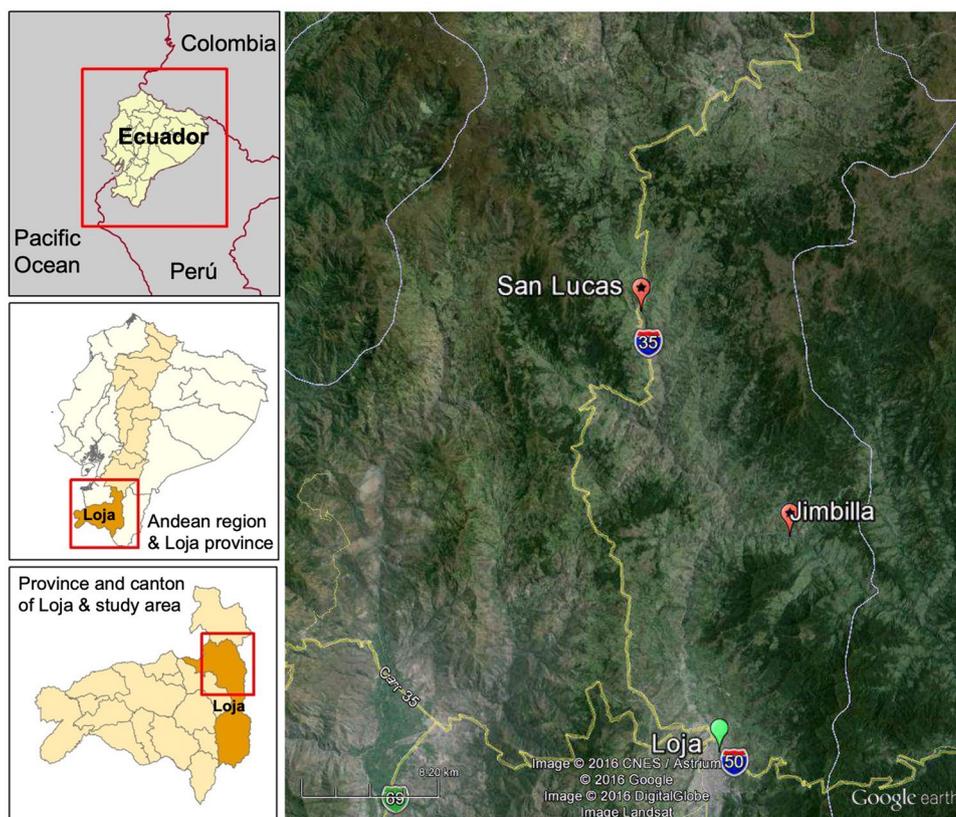
### Theoretical and methodological framework

In order to conceptualize and analyze the agri-food system as a whole, we have made use of the socio-ecological systems (SES) and the food sovereignty conceptual frameworks.

Ostrom (2009) developed the SES model to analyze complex systems. It tackles both ecological and socio-economic elements of the system and organizes them into Actors (A), Governance System (GS), Resource Systems (RS) and Resource Units (RU). Within this conceptualization, the elements are impacted by external drivers of change, both socio-economic (S) and ecological (ECO). The model analyzes how these drivers affect the components of the system through interactions (I) that result in different outcomes (O) and a new configuration of the system. One important characteristic of the model is that it systematically organizes all components of the system into different tiers of variables. To analyze current configurations of the agri-food system within a case study, we developed an integrated framework that links the social and ecological components of the agri-food system conceptualized as an SES to the food sovereignty as described by Ruiz-Almeida and Rivera Ferre (2019) (Fig. 1). To this end, we adopted Ostrom’s terminology to classify the second-tier variables of the SES framework (McGinnis and Ostrom 2014) (Appendix 1 in Table 2).

The food sovereignty framework was developed by the international peasant movement La Vía Campesina (LVC) in 1996 as an alternative to the globalized and industrialized food system challenging the current food regime (McMichael 2011). The most commonly used definition of food sovereignty is the one that emerged from the Declaration of Nyéléni, first drafted at a forum held in Mali in February 2007, which states that: “Food sovereignty is the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems. It puts the aspirations and needs of those who produce, distribute and consume food at the heart of food systems (...)”. (Nyéléni Movement for Food Sovereignty 2015). LVC describes the food sovereignty movement as a counter-hegemonic “movement of movements” that, through collective action, attempts to radically transform the neo-liberal food regimen in favor of an environmentally sustainable and socially just agri-food system (La Via Campesina 2009; McMichael 2011). Many scholars agree that this policy proposal has the potential to reduce hunger and rural poverty (Altieri 2009; Wittman 2011) and further the move towards sustainable rural development (Rosset et al. 2011). On more of a policy level, multilateral institutions (e.g. the UNEP, the Commissioner of the Right to Food, the FAO, the UN Committee on Food Security) and governments (e.g. those

**Fig. 2** Study area: parishes of San Lucas and Jimbilla in the Province of Loja, a region of southern Andean Ecuador



of Mali, Nepal, Indonesia, Ecuador, Bolivia) have acknowledged its potential in the development of sustainable agri-food systems (Brem-Wilson 2015). To analyze the potential of food sovereignty in achieving sustainability goals, indicators have been developed at both the local (Binimelis et al. 2014) and global (Ortega-Cerdà and Rivera-Ferre, 2010; Ruiz-Almeida and Rivera-Ferre 2019) levels. Measuring food system outcomes in terms of food sovereignty allows new trends to emerge that will be useful for policy-makers (see Oteros-Rozas et al. 2019). For this case study, we used indicators related to five food sovereignty pillars adapted by Ortega-Cerdà and Rivera-Ferre (2010): (1) Access to Resources, which includes the access human, financial and natural resources; (2) Production model, which refers to both the land and labor organization and the management practices adopted based on agroecology; (3) Transformation and Commercialization, which includes indicators of transformation practices, prices, access to markets; (4) Food Security and the Right to Food, which includes indicators of the food and nutritional security, but also access to culturally appropriate food and dependence from buying food; (5) Agrarian policies and Civil Society Organizations, which include degree of organization, participation and lobbying capacity of peasants.

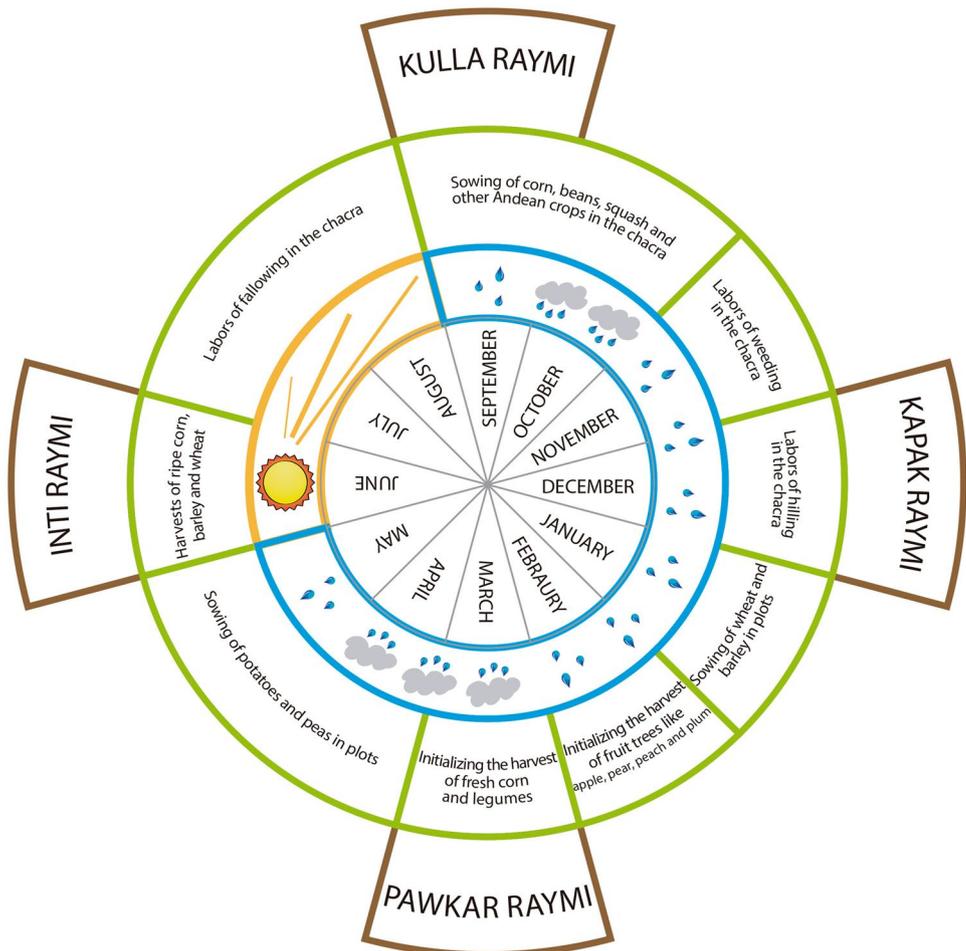
## Methodology

### Background information on the case study

Our study focuses on the Andean agro-ecosystem in the canton and province of Loja, located in the southern Ecuadorian Andes, in the parishes of *San Lucas* ( $3^{\circ} 44' 47.5''$  S,  $79^{\circ} 15' 58.5''$  W) and *Jimbilla* ( $3^{\circ} 51' 39.5''$  S,  $79^{\circ} 10' 22.2''$  W) (Fig. 2).

The agricultural calendar for this region (Fig. 3) has a rainy season from September to May and a dry season from June to August. The agricultural calendar is linked to traditional Andean indigenous celebrations (shown in the outer circle). The rainy season corresponds to September to May (periods of high rainfall are usually during October and March–April), and the dry season to June to August. Kulla Raymi (a Quichua word that means Queen festival dedicated to the moon) begins on September 21. The crops cultivated in this season are: corn associated with bean, squash and other Andean crops. Following the summer austral solstice (Kapac Raymi, which in Quichua means wisdom festival), barley and wheat are planted in January. After March 21 (Pawkar Raymi, or flowering festival in Quichua), the fresh bean harvest begins. In April, potatoes and peas are planted. On June 21, Saraguro and other ancestral communities celebrate the Sun festival (Inti Raymi, in Quichua) and this

**Fig. 3** Agricultural calendar for the area of study, canton of Loja, Ecuador. Source: informal interviews and MBS-SSDR/IFAD/IICA 1991, Neill and Jørgensen 1999, INPC 2012, INAMHI 2014b. Author's own data



is the period of the ripe corn, barley and wheat harvests (MBS-SSDR/IFAD/IICA 1991; Neill and Jørgensen 1999; INAMHI 2014a; INPC 2012). The area where corn is grown alongside Andean crops (e.g. beans, potatoes) is locally known as *chacra*, while the *huerta* is mainly dedicated to planting short-cycle vegetables. Crops are also distributed according to altitude.

Provincial data show that the population of Loja canton corresponds to 2.5% of the country's total population. It is predominantly urban (79%) and *mestizo*<sup>1</sup> (83%), the indigenous population (10%) comprising a considerably smaller proportion of the total population (INEC 2010). For 48% of the population, income derives from on-farm activities (INEC 2010), while off-farm work is also a relevant strategy of income generation for 63% of the population (of the latter, 34% is not related to the agricultural sector) (INEC 2010). Only 14% of agricultural production units (APUs) sell their production directly to consumers (SINAGAP 2000), while

51% are smaller than 5 ha and occupy 6% of the land area. The largest units (which are over 100 ha) represent 2% of local APUs, occupying 40% of the land area.

The largest indigenous group is the *Saraguro* people, a large and diverse Quechua group (INPC 2012). Though the *Saraguro* agro-pastoralist society has been heavily transformed and the economy diversified in recent times, including receiving income through remittances due to high rates of migration to the US and Spain, most *Saraguros* maintain their distinctive ethnic identity through ceremonies, clothing, observing the *wakas*, i.e. natural sacred beings, etc. *Saraguro* culture still maintains an agro-centric spirituality and knowledge system (Bacacela 2010).

The indigenous peoples and *mestizos* live within community-based organizations, i.e. the traditional indigenous *comunas* and farmers' associations. The *comunas* are groups of indigenous people with formal rules drafted in coordination with the Ministry of Agriculture (Martínez 1998). These organizations are governed by the Law of Commons (1937) and have the *cabildo* as their representative body (Martínez 2002). In *Saraguro* communities, the *cabildo* is therefore the central entity of political organization (Ávila

<sup>1</sup> Cultural and biological mix of Spanish and indigenous people (Belote 2002).

2012; INPC 2012). Land ownership is individual and neither the community nor its leaders control rights over the land or water supply (Belote 2002). However, mobilizations by *Saraguro* communities in relation to land struggles played a decisive role in an indigenous uprising during the 1990s (Rosero 1990, cited in Criollo 1995, p. 164), and the community currently plays a key role in decision-making on land uses and economic activities, such as communitarian tourism (Ordoñez Sotomayor and Ochoa Cueva 2020).

Mostly organized by women, the RAL was created as a novel institutional arrangement in 2006. It comprises both indigenous (i.e. *Saraguro*) and *mestizo* traditional farmers' organizations and is linked to the transnational peasant movement *La Vía Campesina*. The RAL was created as a response to rapid socio-economic, cultural and political changes that were affecting both social organization and culture (Martínez 2005, 2002), the loss of traditional crops and foods (Espinosa 1997; Sherwood et al. 2013) and the progressive dependence on intermediaries in urban markets (Proaño and Lacroix 2013; Chiriboga and Arellano 2004). As in other cases of agroecological counter-movements in Ecuador, the emergence of RAL met with a favorable political environment, i.e. the new Constitution of Ecuador adopted in 2008 (Asamblea Nacional 2008), which included food sovereignty as a strategic objective (Art. 281) (Intriago et al. 2017). Additionally, in 2009, the Food Sovereignty Law (LORSA) was approved to provide a legal framework for food sovereignty. At the time of this study, the RAL was composed of 17 producer organizations and had established three associative spaces in the city of Loja in the form of weekly agro-ecological fairs. At the core of the RAL's governance system is the Participatory Guarantee System (PGS). PGS are networks created within local communities that provide certification for producers based on active participation by stakeholders and are built on a foundation of trust, social networks and knowledge exchange (Loconto and Hatanaka 2018). The RAL uses the PGS as a validation tool for implementing agroecology at the farm level and as a consumer warranty regarding the type and quality of products. The RAL is coordinated with the municipality of Loja and the local public university for the access to local markets and training.

### Data collection

First, a literature review was conducted in order to collect context-specific data and complementary information and have references to other mountain area studies. In order to design the survey, informal visits were undertaken to the area in December 2014 to carry out in-depth interviews with key informants (N = 14). The survey was then administered in four communities in the parishes of *San Lucas* and *Jimbilla*. The sample was deliberately skewed in order

to capture the cultural, institutional and ecological diversity of the agrarian dynamic in this Ecuadorian Andean region (Cepeda, Gondard, and Gasselín 2007). Regarding cultural diversity, both indigenous *Saraguro* (N = 59) (81% of the San Lucas population) and *mestizo* households (N = 57) (95% of the Jimbilla population) were interviewed (INEC 2010). To cover institutional diversity, we also included a number of households in the communities that belonged to indigenous *comunas* (N = 34) and the RAL (N = 24). Finally, to capture ecological diversity, the interviewed households were located in different altitudinal zones, from low (1800–2200 m.a.s.l.; N = 24) to middle (2200–2600 m.a.s.l.; N = 61) and high (2600–3000 m.a.s.l.; N = 31) zones (Cueva 2010). The survey participants comprised 60% women and 40% men (householders aged between 18 and 89 years). The questionnaire included information on: (i) household (e.g. size and division by age and gender) and individual (e.g. ethnic self-identification and educational level) characteristics; (ii) production activities (e.g. access to and uses of land, credit, training, agricultural practices, crops and livestock management, commercialization); (iii) processing and distribution activities (e.g. artisanal processing, commercialization, access to markets and incomes sources); (iv) consumption activities (e.g. consumption habits); and (v) social relations (e.g. participation in social exchanges such as *minga* [exchange of work for food, mainly for community purposes], *prestamos* or *randi-randi* in Quechua [exchange of work for work, mainly at the household level], exchange of seeds and community-based organizations. All survey sections included questions about: rights (e.g. access to land); agency (e.g. decisions about crops and livestock management); and power (e.g. role of gender in division of tasks and responsibilities within the household in the different agri-food activities).

### Data analysis

We qualitatively analyzed the content of interviews from key local informants, and triangulated this information with the literature review to define and classify a series of variables that describe the configuration of the agri-food system. These were classified as explanatory (i.e. those variables from Actors and Governance subsystems that might influence the behavior of other components and their interactions), intermediate (i.e. those variables that are relevant in influencing the configuration of agri-food activities but at the same time can be influenced by other explanatory variables targeted by our study), or control variables (i.e. those variables that could influence the configuration of agri-food activities but did not form part of our target study goal). Some of these variables also influence the components of agri-food activities (dependent variables, in our case, linked to food sovereignty pillars).

A Redundancy Analysis (RDA) was performed to select the main variables influencing the configuration of the agri-food system. RDA is a form of constrained ordination that examines how much of the variation in one matrix of explanatory variables explains the variation in another matrix of response variables (Leps and Smilauer 2003). The explanatory and control variables were included within the explanatory matrix, and the dependent and intermediate variables were included within the response matrix. Prior to performing the RDA, we applied a log-transformation (Leps and Smilauer 2003) to all of the numerical and ordinal variables.<sup>2</sup> In order to exclude collinear variables from the model, we performed a collinearity test using the variance inflation factor (VIF); a VIF > 10 indicates that a variable has a high level of collinearity (Zuur et al. 2010; Oksanen 2013). We then applied a model-building technique to reduce and find the significant variables (from the explanatory matrix) that determine the configuration of the agri-food system (i.e. response matrix) in this case study. Model building was performed using the *step* function (Oksanen 2013) from the Community Ecology Vegan R Package software (Oksanen et al. 2015). The *step* function uses Akaike's information criterion (AIC) to select the best model from among all the possible combinations of available variables within the explanatory matrix. To validate the model's prediction, the function uses a permutation test at each step. Thus, all included variables in the final model are significant and all excluded variables not significant (Oksanen 2013). The results of the RDA were visualized using a biplot graph.

In order to evaluate the key role socio-economic and institutional factors play in components of agri-food activities, we conducted non-parametric bivariate tests<sup>3</sup> using SPSS statistics for each significant variable obtained from the RDA. Finally, to understand the configuration of the agri-food system in terms of food sovereignty, we linked the five food sovereignty pillars with significant dependent and intermediate variables for each agri-food activity.

An overview of the variables used for the different analyses performed in the study and their links to food sovereignty pillars is provided in Table 1 and Appendix 2 in Table 3.

## Results

Our results indicate a statistically significant association ( $p < 0.0001$ , from 999 permutations) among the most relevant institutional and socio-economic factors that determine

the configuration of the agri-food system in our case study. The results of the RDA analysis and the biplot representation are shown in Fig. 4. The RDA mainly revealed the trade-off association between income generation strategies (on-farm strategies vs off-farm work) and ecological (RU5.1; RU5.2; RU6.1) and economic (A8.5) diversification. The analysis also revealed that households with larger land size (RS3 Land size) often have on-farm income generation strategies. Two further explanatory variables, i.e. membership to RAL and belonging to the indigenous *Saraguro* culture, were mainly associated with agroecological production practices (A9.1; A9.2; A9.3), a dependence on purchased food (A8.4), seed exchanges (A6.3), access to human resources (A2.5) and to market (GS5.1).

In order to better understand how selected explanatory variables positively or negatively influence other variables of the agri-food system in the four activities (i.e. production, transformation process, distribution, consumption), bivariate tests were performed (see Fig. 5 and Appendix 3 in Table 4 for details). Links with food sovereignty pillars were also analyzed.

### On-farm income generation strategies

This variable correlated positively with number of cattle (RU5.3), crop (RU5.1) and small animal (RU5.2) richness in production activities, i.e. production model pillar. With regards to distribution activities, on-farm income generation strategies displayed a positive correlation with income diversification (A8.5), i.e. production model pillar. With regards to consumption activities, a positive correlation was found with dietary diversity produced (RU6.1), and a negative one with importance of small animals for self-consumption (A8.2) and the dependence of non-traditional purchased foods low in micronutrients (A8.4), i.e. food security and right to food pillar.

### Off-farm work income generation strategies

The variable off-farm work displayed a negative correlation with agroecological practices, such as the use of ethno-veterinary products (A9.3), i.e. production model. Pillar. Concerning distribution activities, off-farm work had a positive correlation with participation in community-based working groups (A6.1), i.e. social organization pillar, which in turn also influenced income diversification (A8.5), but it displayed a negative correlation with importance of on-farm incomes (A8.6), production model pillar. With regards to consumption activities, off-farm work had a negative correlation with dietary diversity produced (RU6.1), i.e. food security and right to food pillar.

<sup>2</sup> We used  $\ln(x)$  for this, and for those variables that range from zero,  $\ln(x + 1)$ .

<sup>3</sup> The Mann–Whitney-*U* test was used for numerical variables, and the chi-squared test for nominal, dummy and ordinal variables.

**Table 1** Summary of the third-tier SES variables (linked to food sovereignty indicators) obtained from the households' questionnaires responses (N=116) and used for the different analysis performed in the study

First-tier †	Second-tier ‡	Third-tier: indicators	Description	Type variable (dummy, numeric or nominal)	Attributes	Food sovereignty pillar
RS	RS3	RS3.1—Size of farm	Land area by household: hectares	Numeric	Number	Access to resources
	RS4	RS4.1—Access to roads paved	If the rural town have access to main roads paved	Dummy	1: yes; 0: no	Access to resources
RS5	RS5.1	Production of processed dairy	Production of processed dairy: fresh cheeses, kg per week (1 kg = 7.7 l of milk)	Numeric	Number	Production model
RS9	RS9.1	Location in altitudinal zones	Low zone: 1800–2200 m.a.s.l Middle zone: 2200–2600 m.a.s.l High zone: 2600–3000 m.a.s.l. <sup>a</sup>	Nominal	LowZone MiddleZone HighZone	Production model
	RS9.2	Location in protected area	If the community is located within protected area	Dummy	1: yes; 0: no	Production model
	RU5	RU5.1—Crop richness	Specific richness of farmed species (except medicinal and ornamental)	Numeric	Number	Production model
RU	RU5.2	Small animal richness	Number of types of small bred animals. Types considered include: sheep, pig, poultry, guinea pigs, beekeeping and aquaculture	Numeric	Number	Production model
	RU6	RU6.1—Dietary diversity produced	Dietary produced diversity (in the last year) regarding the food micro-nutrients: WDDS index <sup>b</sup> . It constitutes the potential of the farm as source of highly nutritious food	Numeric	Number	Access to resources Right to food
GS	GS4	GS4.1—Land tenure	Legal status of land	Nominal	Properties: Without titles Only with titles Both (with & without titles)	Access to resources
	GS5	GS5.1—Access to retailing location	If at least one household member has a retail location in local markets	Dummy	1: yes; 0: no	Agri-food policies & Local markets
GS6	GS6.1	Member of agro-ecological network of Loja (RAL)	If at least one household member belongs to community based organization called <i>Red Agroecológica Loja</i> (RAL)	Dummy	1: yes; 0: no	Social organization
A	GS6.2	Member of community-based organizations ( <i>Comunas</i> )	If at least one household member belongs to community based organization called <i>Comuna</i>	Dummy	1: yes; 0: no	Social organization
	A1	A1.1—Size of labor force	Number of people in household with > 15 years	Numeric	Number	Production model
		A1.2—Gender of respondent	-	Dummy	1: female; 0: male	-

Table 1 (continued)

First-tier †	Second-tier †	Third-tier: indicators	Description	Type variable (dummy, numeric or nominal)	Attributes	Food sovereignty pillar	
A2	A2.1—Self-identification as <i>Saraguro</i> indigenous	A2.1—Self-identification as <i>Saraguro</i> indigenous	Regarding the culture, if the household is self-identified as <i>Saraguro</i> indigenous	Dummy	1: yes; 0: no	Social organization	
			A2.2—Gender equality in the distribution of labor responsibilities	If 50% or more of activities are performed by both (female and male). Activities considered are: eight to agricultural production and animal production according to animal types in the household, three to processing (food preservation to self-consumption, dairy and non-dairy products to sell), three to distribution (crops, livestock, dairy products), and one to off-farm works	Dummy	1: yes; 0: no	Production model
A6	A2.3—Marketing of agri-food products	A2.3—Marketing of agri-food products	If household has as strategy of income generation the marketing of some agri-food product (crops, cattle, small animals and/or their products)	Dummy	1: yes; 0: no	Local markets	
			A2.4—Off-farm work	If household has as strategy of income generation the off-farm work	Dummy	1: yes; 0: no	Production model
			A2.5—Access to training	If at least one household member during the last year received a training	Dummy	1: yes; 0: no	Agri-food policies & Access to resources
			A2.6—Access to credit	If at least one household member during the last year had access to credit	Dummy	1: yes; 0: no	Access to resources
			A6.1—Participation in community-based working groups	If at least one household member during the last three years participated in working groups convened by the community ( <i>mingas</i> )	Dummy	1: yes; 0: no	Social organization
			A6.2—Participation in services exchanges	If at least one household member participated during the last three years in exchanges of services-services	Dummy	1: yes; 0: no	Social organization
A8	A6.3—Participation in seeds exchanges	A6.3—Participation in seeds exchanges	If at least one household member during the last three years participated in exchanges of seeds	Dummy	1: yes; 0: no	Social organization	
			A8.1—Importance of crops for self-consumption	Proportion of crops for HH consumption (from total of species farmed)	Numeric	Number	Right to food
	A8.2—Importance of small animals for self-consumption	A8.2—Importance of small animals for self-consumption	Proportion of small animals for HH consumption (from total of types of small bred animals)	Numeric	Number	Right to food	

Table 1 (continued)

First-tier †	Second-tier †	Third-tier: indicators	Description	Type variable (dummy, numeric or nominal)	Attributes	Food sovereignty pillar
	A8.3—	Importance of traditional foods	Frequency of consuming corn—traditional food (times per week) <sup>c</sup>	Ordinal	1: low 2: medium 3: high	Right to food
	A8.4—	Dependence of non-traditional purchased foods low in micronutrients	Frequency of consuming noodles—purchased food (times per week) <sup>c</sup>	Ordinal	1: low 2: medium 3: high	Right to food
	A8.5—	Income diversification	Diversification of incomes within the household. The types considered are: five on-farm incomes (sell of crops, dairy and non-dairy products, small animals, and cattle), one off-farm incomes (works), and three non-farm incomes (government subsidies <i>Bono de Desarrollo Humano</i> , remittances, land lease)	Numeric	Number	Production model
	A8.6—	Importance of on-farm incomes	Proportion of income diversification due to on-farm incomes	Numeric	Number	Production model
	A8.7—	Dependence on middlemen	Selling (crops & dairy) to middlemen	Dummy	1: yes; 0: no	Local markets
	A8.8—	Weekly frequency of sell	Frequency of selling (times per week)	Ordinal	0: no sold 1: sells, but less than once 2: once 3: more than once	Local markets
A9	A9.1—	Use of organic inputs on crops	If they use organic inputs to control pests. Including the <i>bioles</i> <sup>d</sup>	Dummy	1: yes; 0: no	Production model
	A9.2—	Use of chemical inputs on crops	If they use chemical inputs to control pests	Dummy	1: yes; 0: no	Production model
	A9.3—	Use of ethno-veterinary products	If they use ethno-veterinary products to control diseases on small animals	Dummy	1: yes; 0: no	Production model

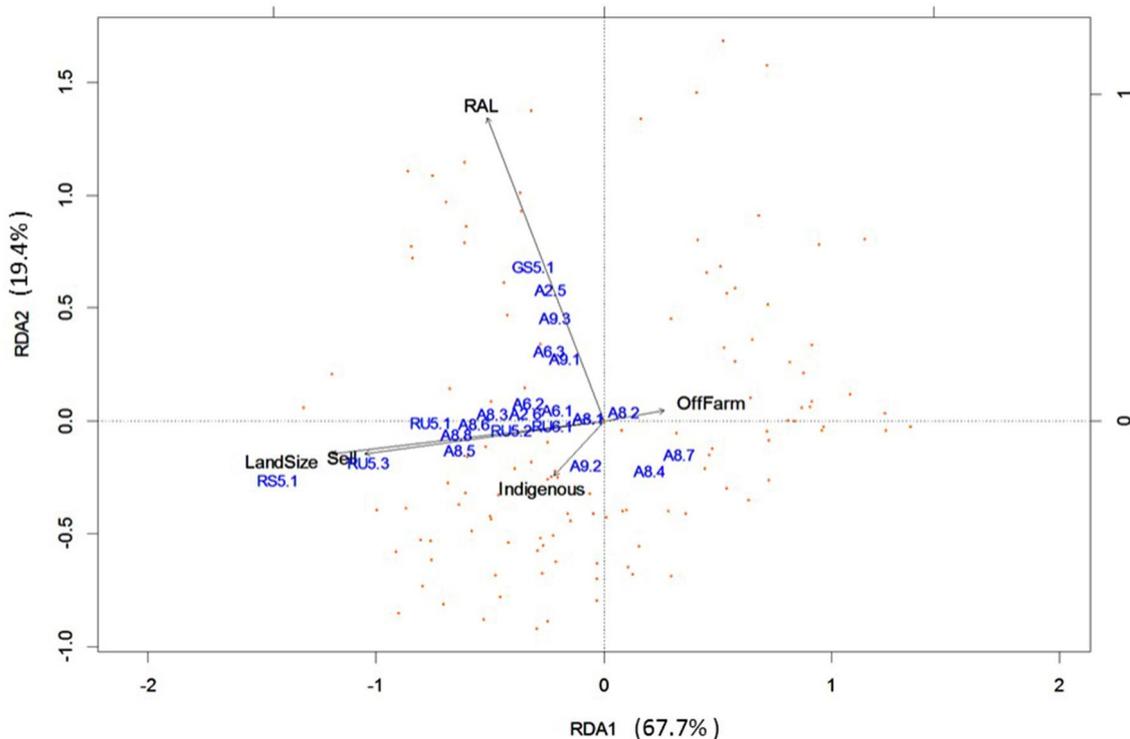
*RS* agro-ecosystem boundaries, *RS3* size of resource system, *RS4* human-constructed facilities, *RS5* productivity of system, *RS9* location, *RU* agro-ecosystem units, *RU5* number of units, *RU6* distinctive characteristics, *G5* agri-food governance system, *G54* property-rights systems, *G55* operational-choice rules, *G56* collective-choice rules, *A* agri-food system actors, *A1* number of actors, *A2* socioeconomic attributes, *A6* social capital, *A8* importance of resource, *A9* technology available

<sup>a</sup>Zoning based on direct observation and cartographic information about the classification of vegetation units (Cueva 2010). The altitudinal range, from about 1800 to 3000 m.a.s.l., corresponds to a temperate climate (Cepeda et al. 2007, p. 46)

<sup>b</sup>WDDS index, based on *Women's Dietary Diversity* Project designed by FAO (Kennedy et al. 2013)

<sup>c</sup>Frequency: low = sells, but 1 time or less/week; medium = 2–3 times; high = 4 times or more

<sup>d</sup>*Bioles* are solutions prepared on a fermentation of natural herbs which have a double function: pest control and crop nutrition



**Fig. 4** Redundancy analysis biplot showing the explanatory and control variables (labeled in black on arrows) that explain the configuration of the third-tier SES dependent and intermediate variables

(labeled in blue). Small red circles represent the households surveyed on study (N=116). Percentage variance explained: RDA 1 (67.72%), RDA 2 (19.36%)

### The indigenous *Saraguro* culture

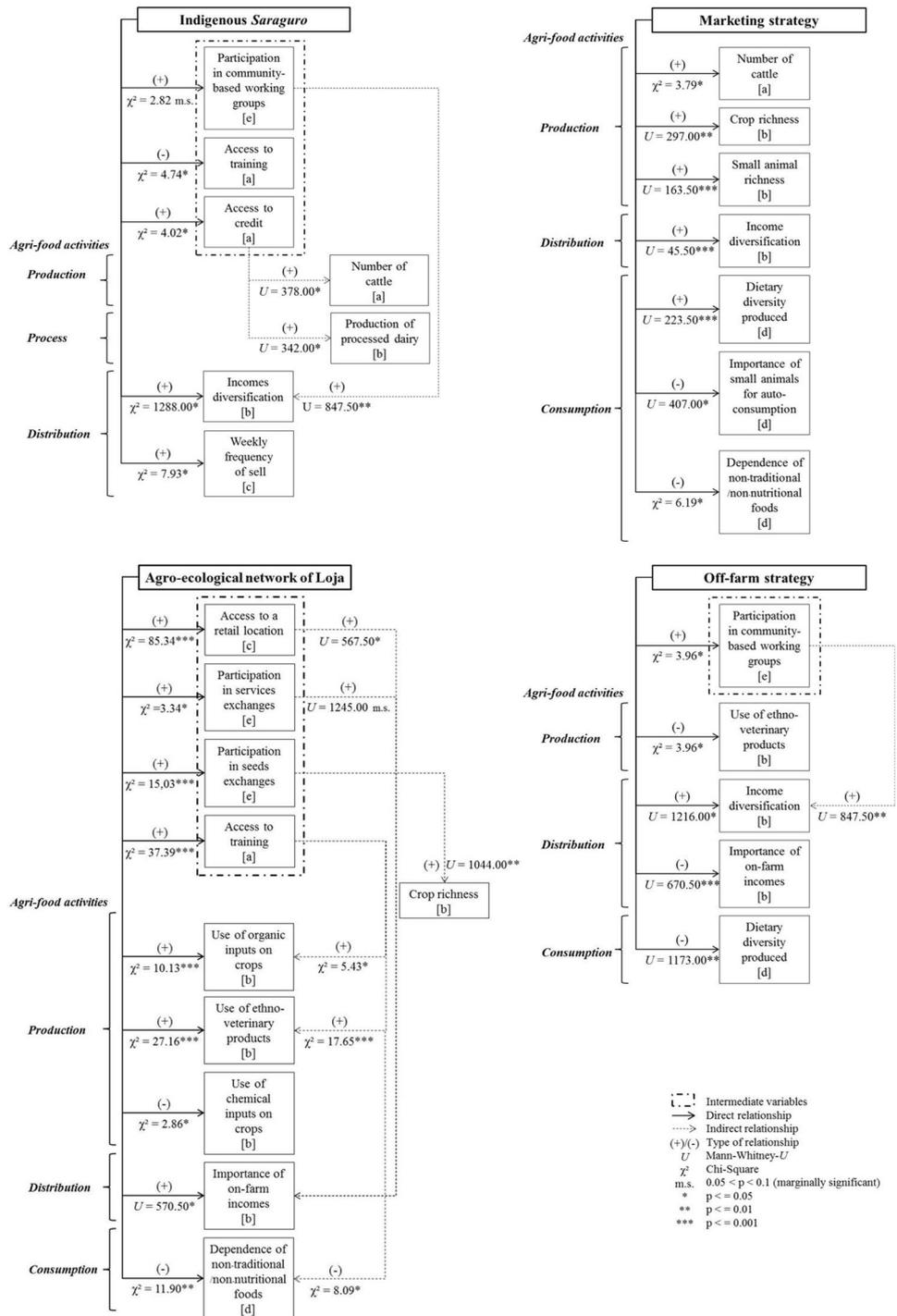
With regards to production and processing activities, indigenous *Saraguro* communities has a positive correlation with access to credit (A2.6) and a negative one with training (A2.5), i.e. access to resources. Furthermore, access to credit positively influenced number of cattle (RU5.3) and processed dairy production (RS5.1), access to resources and production model pillars. According to our survey and interviews, access to credit in the study area has occurred mainly through savings and credit cooperatives (69%), i.e. through the private sector. With regards to distribution activities, being *Saraguro* had a positive influence on weekly frequency of selling (A8.8). Additionally, being *Saraguro* has a marginally significant positive correlation with participation in community-based working groups (A6.1), social organization pillar, which in turn also influenced income diversification (A8.5), i.e. production model pillar.

### RAL collective rules

With regards to production activities, the RAL collective's rules displayed significant positive correlations with agroecological practices, such as the use of organic inputs on

crops (A9.1) and ethnoveterinary practices (A9.3); and a negative correlation with conventional practices, such as the use of chemical inputs on crops (A9.2), i.e. production model pillar. Additionally, the RAL collective's rules has a significant positive correlation with access to training (A2.5), which in turn also influenced agroecological practices. Participation in seed exchanges (A6.3), i.e. social organization pillar, was also found to correlate with RAL, influencing crop richness (RU5.1), production model pillar. With regards to distribution activities, the RAL had a significant positive correlation with importance of on-farm incomes (A8.6), i.e. production model pillar. Additionally, the RAL had significant positive correlation with participation in services exchanges (A6.2), social organization, and access to retail location (GS5.1), i.e. commercialization, which in turn also influenced the importance of the on-farm income variable. With regards to consumption activities, the RAL had a significant negative correlation with dependence on non-traditional purchased foods low in micronutrients (A8.4), i.e. food security and right to food, which in turn was also influenced by training.

**Fig. 5** Description of the role played by the following explanatory variables: *Indigenous Saraguro*, *marketing of agri-food products* and *off-farm works*, *Agroecological network of Loja (RAL)* in configuring the agri-food system through agri-food activities. The diagram shows the statistical significance of the relationship between each explanatory variable and their intermediate and dependent variables. Letters within brackets show how each component of the agri-food system relates to the food sovereignty pillars: **a** access to resources, **b** production model, **c** local markets, **d** right to food, **e** social organization



## Discussion

### Do economic factors matter when it comes to configuration of the agri-food system and food sovereignty goals?

First of all, our results confirm that the commercialization of agri-food products as an on-farm strategy for income

generation, through both normal local market and PGS mechanisms, contributes to income diversification within the household, as suggested in the literature (Minot et al. 2006). Secondly, this strategy influences agro-biodiversity at the farm level, as suggested for other contexts by Major et al. (2005) and Trinh et al. (2003). Households that market their own agri-food products had higher levels of diversity in terms of crop and animal richness; and, as noted by other

studies (Herforth 2010; Jones et al. 2014), this richness is associated with high levels of dietary diversity produced. In sum, the commercialization of agri-food products increases control over food sovereignty in the production model and right to food pillars. Moreover, through the positive influence of on-farm production diversity the diversity it also increases the diversity of households diets, an important nutritional outcome associated with the nutrient adequacy of diets and individuals' nutritional status (Jones et al. 2014). The results illustrate that such households have low levels of dependence on non-traditional purchased foods low in micronutrients. Since food consumption of low nutritional quality, especially in areas with fewer economic resources, is a public health problem in Ecuador (Freire et al. 2013), these results are important for understanding the potential capacity of local agri-food systems to meet human nutritional needs in fragile and marginal areas, i.e. to impact food sovereignty in the right to food pillar. However, our results also show that households that market their own agri-food products score lower in own consumption of small animals, due to the fact that they sell them. This is an undesirable outcome related to the consumption of nutritional foods within the right to food pillar, and is consistent with the findings of recent studies performed in the Ecuadorian Andes (Oyarzun et al. 2013; Berti et al. 2014) as well as studies found elsewhere in the Andean region (Berti et al. 2010).

Regarding the influence of off-farm work on the configuration of the agri-food system, we found that this type of strategy supports income diversification (Ellis 2000), helping to increase farm income for rural households living at subsistence level and thus, to diversify against risk (Reardon et al. 2001; Lanjouw 1999). However, it also leads to lesser importance for revenue obtained from the marketing of farm products and a lower dietary diversity, which can influence the food consumption at the household level. Given that the production model is intensive in labor in the region concerned, this lower diversification may influence the reduction of available labor within households for agriculture (Rozelle et al. 1999; Pfeiffer et al. 2009). In sum, families with an off-farm strategy have a deficit of control over the production model and the food security and right to food pillars of food sovereignty. Unexpectedly, our findings reveal a relationship between participation in the community based on ties and work (social organization pillar), expressed through *mingas*, and income diversification (production model pillar). In respect of this, other studies have shown the importance of social ties in securing off-farm work by linking farm residents to jobs outside the farm property and/or influencing their likelihood to participate in off-farm work (Vanwey and Vithayathil 2013). That being said, however, we cannot fully confirm these findings from the available data, especially given that other studies on Ecuadorian Andean communities (Martínez 1996) have

noted that *mingas* (e.g. communal works such as water supply and road construction) are implemented when communal action participation is high. Therefore, this variable could be acting as a contextual factor. Finally, regarding the economic characteristics of the household, our results suggest that livelihood decisions are strongly affected by the amount of land owned by the family. Households with small farms are more likely to have off-farm work in order to diversify their income sources (Escobal 2001; Lanjouw 1999), while having more land means being able to maintain livestock, the main activity linked to an on-farm income generation strategy in the area of study (Belote 2002; Pohle et al. 2010).

To sum up, then, our findings suggest that generating income through an off-farm strategy interacts with food sovereignty goals in opposing ways, specifically by decreasing the control over the production model and right to food pillars, while also increasing the household's social organization and, thus, its diversification.

### **Does belonging to *mestizo* or indigenous communities matter in the configuration of the agri-food system and food sovereignty goals?**

The Andean research community has highlighted the role of socio-cultural characteristics that link indigenous cultures and knowledge to local configuration of the agri-food system and adaptation to changes (Garay and Larrabure 2011; Velásquez-Milla et al. 2011). Our findings contribute to those of the aforementioned studies, showing that indigenous communities and their social capital facilitate access to other forms of capital, both directly and through engaging with State, market, and other civil society actors (Bebbington and Perreault 1999; Perreault 2003). This influence can be assessed through both ecological and socio-economic components of the local agri-food system. Being part of the indigenous culture therefore facilitates access to credit, mainly to support livelihood strategies related to livestock management (i.e. the production model pillar). This result is corroborated by those from other studies on *Saraguro* culture and shows that livestock ownership (jointly with land) is an indicator linked to success in local livelihoods (Belote 2002), which are mainly based on keeping animals and income from selling cheese (Belote 2002; Pohle et al. 2010). In line with other research (Belote and Belote 2005), our findings show that *Saraguro* people also display high diversification when it comes to income, given that migration to urban areas and/or foreign countries has been an common adaptation strategy. In respect of this, access to a paved road in San Lucas parish is a contextual factor that positively links to being part of *Saraguro* communities and would appear to be relevant to distribution activities, thus influencing sales frequency and income diversification. This result corroborates other findings showing that access

to road infrastructure systems has a cascade effect on access to local markets, the development of multiple activities and income diversification (Castaing et al. 2015; Bernardi De León 2009).

All that being said, access to training is negatively related to the *Saraguro* indigenous group, and we observe here that they have less access than *mestizo* people to the information necessary to adopt agricultural practices (González et al. 2010). Thus, our results confirm that indigenous people rely more on local and horizontal networks within the community and traditional ecological knowledge for farming (the social organization pillar of food sovereignty). However, no difference was found to be associated with membership of the *comuna* or not. As noted by Belote (2002), *Saraguro* communities do not act as regulatory units, which may explain why this institutional factor was not significant in the indicators used here describing the local agri-food system.

In sum, from a food sovereignty perspective, our results suggest that in the configuration of the local agri-food system in Loja, indigenous *Saraguro* culture plays a central role in positively influencing social organization, and therefore control over access to resources, the production model and local markets.

### Does participating in the RAL matter when it comes to configuration of the agri-food system and food sovereignty goals?

Our findings make a further contribution to studies based on agri-food sociology and agroecology research by showing that collective organization under the agroecological paradigm is the core on which food sovereignty components are built (Rosset et al. 2011; Simoncini 2015; Gyau et al. 2014; Rosset and Altieri 2017; Oteros-Rozas et al. 2019). In our case, the *RAL* facilitates access to training (specifically in this case, agroecological training through contacts with the local public university) and participation in seed exchange (i.e. access to the resources pillar), which in turn positively influences the adoption of agroecological production practices and agro-biodiversity (i.e. the production model pillar). Prior studies and our key informants both point to the key role played by social organization in the adoption of agroecological practices through a *diálogo de saberes* (dialogue of wisdoms) (Martínez-Torres and Rosset 2014), e.g. in agroecology or farmers' schools (McCune et al. 2014) and/or in meetings organized by these networks as seed exchange fairs (Hermann et al. 2009). With its system of collective rules, of which the PGS constitutes the core, the *RAL* strengthens and monitors the implementation of agroecological practices on the farms owned by its associate producers. Previous studies have also highlighted the key role of PSGs in strengthening agroecological practices (MAGAP 2012; Binder and Vogl 2018).

Being a member of the *RAL* also increases the importance of on-farm income, and access to markets may explain the diversification of income due to on-farm activities within *RAL* households. In fact, this is one of the pillars strengthened most by the *RAL*, due to it performing lobbying activities with the municipality (Vallejo-Rojas, Ravera and Rivera-Ferre 2015). Other Ecuadorian agroecological networks (Chauveau et al. 2010; MAGAP 2012; Proaño and Lacroix 2013) have also achieved these desirable outcomes within distribution activities. Regarding eating habits at the household level, our findings reveal the importance of the *RAL* when it comes to access to training, due to it performing lobbying activities with NGOs and the collective rules and social ties built by the organization. The *RAL*'s collective rules establish that food production must first focus on meeting household nutritional needs, forcing the marketing of agri-food products into second place. This is relevant because it avoids the undesirable effects of indicators linked to the strategy of commercializing agri-food products within the right to food pillar, like those related to low levels of self-consumption (explained above). Additionally, social ties between *mestizos* and indigenous people strengthen the exchange of knowledge in the gastronomic and nutritious fields. Previous studies have also highlighted the role of social networks as determinants of consumer habits (Fonte 2013; Williams et al. 2015). Moreover, the relationship between *RAL* and service exchanges is an important aspect within Ecuadorian Andean communities, where these forms of exchange are becoming increasingly scarce (Martínez 2002). Reciprocity contributes to the development of long-term obligations between people, which is an important part of achieving positive environmental outcomes in agri-food systems (Pretty and Smith 2004). Both prior studies and our key informants indicate that these exchanges are mainly related to on-farm activities (e.g. planting, harvesting) (Martínez 1996; Gray 2009).

In sum, from a food sovereignty perspective these findings suggest that *RAL*'s collective rules play a pivotal role in the interaction between the pillars of social organization and agri-food policy, increasing access to the right to food and production model pillars.

*RAL* is a network led by and mainly comprising women. Like other scholars (Gray 2009), we observed that in rural parishes of Loja province, the number of women working in the farm household increased due to male-driven migration and remittances. Indeed, in our area of study, men are often engaged in off-farm work (Vallejo-Rojas et al. 2015) mainly linked to the construction sector (INEC 2010), which diversifies their sources of income, while women have increased their participation in on-farm labor, confirming an increased female presence in agricultural activities (Deere 2005; Katz 2003). Secondly, we observe that in our case study the adoption of an agro-ecological production model is strictly

related to the existence of a collective agency built by the RAL. Women members of RAL have united their efforts, independently of ethnic and class divisions, and through the organization's rules (at a collective level) achieved the successful adoption of the agro-ecological production model (at a farm level) and access to local markets (at a collective level) by lobbying government and nongovernment organizations. Additionally, in the interviews conducted within this research, women highlighted an increase in self-esteem and economic independence (at an individual level) as a result of participating in the RAL. Despite these data requiring more in-depth research, they confirm the findings of other studies on collective agency and women (Agarwal 2000; Gabrielson and Ramasar 2013; Bezner-Kerr et al. 2019). Recent studies in the Ecuadorian Andean context (Cole et al. 2011) have also suggested that women's greater understanding of crop management options and more equal household gender relations are associated with conventional practices being less widespread.

## Conclusions

By combining the SES and food sovereignty frameworks in a local Ecuadorian Andean case study, we have analyzed which variables and factors interact in the local agri-food system, contributing to an understanding of its current configuration when conceptualized as a social-ecological system. Most food sovereignty-related research to date has shown, mainly through qualitative methodologies, the key role of social organization and collective action as a central component in advancing the proposal for food sovereignty. Our study contributes to this literature by quantitatively demonstrating how being part of the RAL and participating in the PGS foster this proposal in practice.

The links and interacting effects between the variables in our study are complex and non-linear. More research in different contexts is required to determine which cross-scale factors either enhance or pose a barrier to food sovereignty goals, and which are most relevant in promoting household adaptation amid the high uncertainty of global environmental change (e.g. how household diversification fosters risk diversification) or making it more difficult (e.g. off-farm work linked to small farms and lack of access to land). Such an understanding may help future policy

design. Historically, the role played by Ecuadorian governments in agri-food policies has focused on the agro-export model, in detriment of peasant and small-farmer agriculture (Rosero et al. 2011). As a response to this, there has been a progressive emergence, consolidation and expansion of counter-movement spaces aimed at agroecology and food sovereignty (Intriago et al. 2017). Our study focuses on this re-configuration of local agri-food systems and suggests that interventions need to focus on the production model promoted by agro-ecological organizations, while including programs aimed at enhancing the role of formal and informal organizations involving both peasants and indigenous communities, strengthening their alliances with consumers. Similarly, government investments aimed at generally improving the nutrition and health levels of the population should include those collaboration programs with agroecological networks that are likely to have the broadest and greatest impact on consumer habits within the rural sector at the household level and provide greater nutritional diversity. That being said, those agricultural programs that focus on a single crop and off-farm income generation may make small-holder farms and farming families more vulnerable, resulting in poorer ecological, nutritional and economic outcomes of the agri-food system from a food sovereignty perspective. Additionally, regarding policy focusing on conservation, policy-makers interested in promoting the sustainable use of natural resources (soil, water, forest) need to consider not only including communities living in protected areas within conservation programs, but also the role of informal networks to improve the adoption of sustainable local production practices in and around protected areas. In sum, ignoring the role of social and institutional factors could represent a missed opportunity to improve the management of Ecuadorian agri-food systems across scales.

Finally, we would note that, in part, ensuring food sovereignty means not only implementing agroecological solutions but also dealing with power relationships in the productive system and specifically on gender roles, rights and involvement in decision-making (Patel 2012; Bezner-Kerr et al. 2019). This topic certainly deserves more attention in future research.

## Appendix 1

**Table 2** Working definitions for each second-tier SES variables used to describe the agri-food system as SES using the McGinnis and Ostrom framework (2014)

Second-tier	Working definition	References
RS3 Size of resource system	Agroecosystem spatial boundaries, equivalent to a farm, farmland, plot, etc., or to a set of these units	Gliessman (2002), McGinnis (2011)
RS4 Human-constructed facilities	Technological infrastructure for the design and management of the agri-food production systems (e.g., irrigation systems, silos, road systems)	Gliessman (2002)
RS5 Productivity of system	Biomass production from the agro-ecosystem	Gliessman (2002)
RS9 Location	Geographical space where the resource system is located. It can be characterized by a set of environmental factors (e.g., altitudinal variations, precipitation regime) and/or be a clearly defined geographical space with protection to achieve the long-term conservation of nature with associated ecosystem services and cultural values	Gliessman (2002), Dudley (2008), McGinnis (2011)
RU5 Number of units	Biotic factors that form part of the agro-ecosystem	Gliessman (2002)
RU6 Distinctive characteristics	Characteristics of living entities. For example, the micronutrient richness that have the crops and animals	Kennedy et al. (2013), McGinnis and Ostrom (2014)
GS4 Property-rights systems	Defines the relations among people with respect to things, and specifies both duties and obligations	McGinnis and Ostrom (2014)
GS5 Operational rules	Implementation of practical decisions by those individuals who have been authorized (or allowed) to take these actions as a consequence of collective choice processes	McGinnis and Ostrom (2014)
GS6 Collective-choice rules	The processes through which institutions are constructed and policy decisions made, by those actors authorized to participate in the collective decisions as a consequence of constitutional choice processes	McGinnis and Ostrom (2014)
A1 Number of actors	It comprises the labor force defined as the number of people in working age (> 15 years) (they may or may not have employment)	INEC (2014)
A2 Socioeconomic attributes	Characteristics of actors related to social (e.g., ethnic background, education, skills, gender, values, etc.) and economic dimensions	Ostrom and Cox (2010), Anderies and Janssen (2013)
A6 Social capital	Social capital comprises the range of relationships, networks and institutions that allow people to build trust and cooperation. In these sense, it includes: the reciprocity, a norm of behavior that encourages members of a group to cooperate with others who have cooperated with them in previous encounters. The trust, a measure of the extent to which members of this community feel confident that other members will come to their assistance when needed. The networks, ties, not bounded by organized groups that facilitate the informal exchange of information or materials, such as seeds	McGinnis (2011), Meinzen-Dick et al. (2014)
A8 Importance of resource	Actors are dependent on the resource system for a substantial portion of their livelihoods. It includes different types of importance such as: food, cultural and economic importance	(Ostrom 2009)
A9 Technologies available	Practices used by actors for the design and management of the agri-food production systems. Actors can use agro-ecological practices (based on the application of ecological concepts and principles) or modern/conventional practices (based on maximizing short-term production)	Gliessman (2002)

## Appendix 2

**Table 3** Classification of variables of the SES framework in explanatory, control, intermediate and depended variables in order to analyze the agri-food system configuration according to literature review, narratives from key local informants and available observations

Second-tier	Third-tier	Linkages with system interactions and bibliographic references	Key informants a references
Explanatory variables			
GS6	GS6.1—Member of agro-ecological network of Loja (RAL)	It can influence interactions such as production and monitoring activities linked to adoption of agro-ecological models Pretty and Smith (2004), Rosset et al. (2011); distribution activities linked to better access to markets Gyau et al. (2014), Binder and Vogl (2018), Chauveau et al. (2010) and alternative food networks Simoncini (2015); self-organizing activities linked to influence on agri-food policies Rosset et al. (2011)	I-RAL-1, I-ASOR-1, I-MA-1, I-UNL-1
GS6	GS6.2—Member of community- based organizations ( <i>comunas</i> )	It can influence local agri-food system interactions such as self-organizing activities that influence agri-food policies Martínez (2002)	I-COM-1, I-COM-2
A2	A2.1— Self-identification as <i>Saraguro</i> indigenous	It can influence interactions such as production activities linked to sustainable crop management practices Velásquez-Milla et al. (2011), distribution activities linked to incomes from on-farm activities (Winters et al. 2002), and self-organizing activities linked to access to resources Bebbington and Perreault (1999), Perreault (2003)	I-COM-1, I-GADP-1, I-GADP-2
	A2.2—Gender equality in the distribution of labor responsibilities	It can determine the power space within the household in the different agri-food activities Fadiman (2005), Howard (2003); and, it can influence interactions such as production activities linked to reduced use of chemical inputs Cole et al. (2011), and consumption activities linked to improving nutrition at household level Schreinemachers et al. (2015)	—
	A2.3—Marketing of agri-food products	It can influence production activities linked to increased crop diversification Jones et al. (2014), increased dietary diversity and on-farm incomes (von Braun (1995), Herforth (2010), Jones et al. (2014), Minot et al. (2006)	I-RAL-1, I-ASOR-1, I-MA-1
	A2.4—Off-farm work	It can influence production activities linked to decreased crop diversification Winters et al. (2006), Kasem and Thapa (2011) and distribution activities linked to increased income diversification Lanjouw (1999), Marchetta (2013)	I-MA-1, I-FEN-1, I-COM-1, I-ASON-1, I-GADM-1
Control variables			
RS3	RS3.1—Size of farm	It can influence crop diversification Kumar et al. (2012), Winters et al. (2006), Sichoongwe et al. (2014), choice and accumulation of livestock Tegebu et al. (2012), productivity Fan and Chan-Kang (2005) and incomes from on-farm activities Winters et al. (2002)	I-RAL-1
RS4	RS4.1—Access to roads paved	It can influence crop diversification Kumar et al. (2012), Sichoongwe et al. (2014), incomes diversification Castaing et al. (2015) and incomes from on-farm activities Winters et al. (2002)	I-ASOR-1, I-ASON-1
RS9	RS9.1—Location in altitudinal zones	It can influence crop diversification Velásquez-Milla et al. (2011)	—
	RS9.2—Location in protected area	It can influence food production Castro et al. (2015)	—
GS4	GS4.1—Land tenure	Not clear influence among securing land titling and access to credit Domeher and Raymond (2012)	I-COM-1, I-COM-2, I-ASOR-1, I-ASON-1

**Table 3** (continued)

Second-tier	Third-tier	Linkages with system interactions and bibliographic references	Key informants a
A1	A1.1—Size of labor force	It can influence crop diversification Winters et al. (2006), Velásquez-Milla et al. (2011), Kasem and Thapa (2011)	–
	A1.2—Gender of respondent	We included the sex of survey respondents in order to avoid gender bias Twyman et al. (2015)	–
Intermediate variables			
GS5	GS5.1—Access to retailing location	It can influence crop diversification (Kumar et al. 2012; Kasem and Thapa (2011) and farmers' decisions to use middlemen for accessing markets (Abdelali-Martini et al. 2014). Additionally, this access can be determined by institutional factors as membership to farmers groups and/or agro-ecological networks)	I-RAL-1, I-ASOR-1, I-MA-1
A2	A2.5—Access to training	These assets play an important role on crop diversification Kumar et al. (2012), Winters et al. (2006), Kasem and Thapa (2011), and incomes diversification Winters et al. (2002). Additionally, these assets can be determined by social factors as indigenous culture and by institutional factors as membership to farmers groups and/or agro-ecological networks Kasem and Thapa (2011), Hellin et al. (2009), McCune et al. (2014), Isaac (2012)	I-RAL-1, I-ASOR-1, I-MA-1, I-UNL-1
	A2.6—Access to credit	Ibid	I-GADP-1
A6	A6.1—Participation in community-based working groups	These social relations can influence crop diversification (Winters et al. 2006; Fuentes et al. (2012) and income diversification (Winters, et al. 2002). Additionally, these social relations can be determined by social factors as culture Walsh–Dilley (2012) and by institutional factors as membership to farmers groups and/or agro-ecological networks Isaac (2012), Pretty and Smith (2004)	I-RAL-1, I-ASOR-1, I-MA-1
	A6.2—Participation in services exchanges	Ibid	Ibid
	A6.3—Participation in seeds exchanges	Ibid	Ibid
Dependent variables			
RS5	RS5.1—Production of processed dairy	Variable included in terms of processing activities Kristjanson et al. (2007)	–
RU5	RU5.1—Crop richness	Variable included in terms of production activities Kumar et al. (2012), Kasem and Thapa (2011), Velásquez-Milla et al. (2011), Sichoongwe et al. (2014)	–
	RU5.2—Small animal richness	Ibid	–
	RU5.3—Number of cattle	Variable included in terms of production activities Delgado et al. (2008), Kristjanson et al. (2007)	–
RU6	RU6.1—Dietary diversity produced	Variable included in terms of consumption activities Jones et al. (2014), Herforth (2010), Oyarzun et al. (2013)	–
A8	A8.1—Importance of crops for self-consumption	Variable included in terms of consumption activities Marchetta (2013)	–
	A8.2—Importance of small animals for self-consumption	Ibid	–
	A8.3—Importance of traditional foods	Variable included in terms of consumption activities Velásquez-Milla et al. (2011)	–
	A8.4—Dependence of non-traditional purchased foods low in micronutrients	Variable included in terms of consumption activities Freire et al. (2013), Oyarzun et al. (2013)	–
	A8.5—Income diversification	Variable included in terms of distribution activities Marchetta (2014), Winters et al. (2002), Escobal (2001)	–

**Table 3** (continued)

Second-tier	Third-tier	Linkages with system interactions and bibliographic references	Key informants a
	A8.6—Importance of on-farm incomes	Variable included in terms of distribution activities Kasem and Thapa (2011)	—
	A8.7—Dependence on middlemen	Variable included in terms of distribution activities Abdelali-Martini et al. (2014)	—
	A8.8—Weekly frequency of sell	Variable included in terms of distribution activities Nsoso et al. (2004)	—
A9	A9.1—Use of organic inputs on crops	Variable included in terms of production activities Altieri (1995)	—
	A9.2—Use of chemical inputs on crops	Ibid	—
	A9.3—Use of ethno-veterinary products	Ibid	—

*RS* agro-ecosystem boundaries, *RS3* size of resource system, *RS4* human-constructed facilities, *RS5* productivity of system, *RS9* location, *RU* agro-ecosystem units, *RU5* number of units, *RU6* distinctive characteristics, *GS* agri-food governance system, *GS4* property-rights systems, *GS5* operational-choice rules, *GS6* collective-choice rules, *A* agri-food system actors, *A1* number of actors, *A2* socioeconomic attributes, *A6* social capital, *A8* importance of resource, *A9* technology available

<sup>a</sup>Based on previously analyzed narratives from key local informants (Vallejo-Rojas et al. 2015). *I-MA-1* movimiento Agroecológico de América Latina y Caribe (MAELA) & Red Agroecológica Loja (RAL), *I-FEN-1* Federación Nacional de Organizaciones Campesinas e Indígenas (FENOCIN), *I-RAL-1* RAL 1-, *SON-1* “Amigos de la Naturaleza” association, *I-ASOR-1* “San Antonio” association & RAL, *I-COM-1* Comuna “Pueblo Viejo”, *I-COM-2* Comuna “Ramos”, *I-GADM-1* Autonomous decentralized government (GAD) of canton of “Loja”, *I-GADP-1* & *I-GADP-2* GAD of rural parish of “San Lucas”, *I-UNL-1* National university of Loja (UNL)

## Appendix 3



**Table 4** (continued)

Agri-food activities & third-tier SES variables	n <sup>a</sup>	Indigenous <i>Saraguro</i>	Mestizo	RAL	Non-RAL	Marketing of agri-food products	Without marketing of agri-food products	Off-farm work	Without off-farm work
Process		1.04		27.16 ***		1.06		3.96*	
RS5.1—Production of processed dairy	78	9.8 (6.42)	7.70 (4.52)	9.4 (5.75)	8.6 (5.63)	8.8 (5.61)	2.7 (0.0)	8.2 (5.34)	9.4 (5.94)
GS5.1—Access to a retail	105	17.0	19.2	100.0	2.3	18.1	—	16.7	20.0
Location									
% Yes		83.0	80.8	0.0	97.7	81.9	—	83.3	80.0
% No		0.002		85.34 ***		—		0.03	
A6.1—Participation in	116	81.0	65.5	88.2	70.7	74.3	63.6	80.9	62.5
Community-based working									
% No		19.0	34.5	11.8	29.3	25.7	36.4	19.1	37.5
Groups									
$\chi^2$		2.82		1.47		0.16		3.96*	
A8.5—Income diversification	116	4.1 (1.36)	3.5 (1.57)	4.2 (1.38)	3.7 (1.51)	4.0 (1.35)	1.5 (0.52)	4.1 (1.54)	3.4 (1.35)
A8.6—Importance of on-farm	116	1288.00*	56.6 (24.87)	69.6 (17.10)	54.7 (25.90)	62.9 (18.15)	0.0 (0.0)	1216.00*	70.1 (25.14)
Incomes									
$U$		1665.00		570.50*		—		670.50 ***	
A8.7—Dependence on	105	41.5	34.6	17.6	42.0	38.1	—	41.7	33.3
Middlemen									
% No <sup>b</sup>		58.5	65.4	82.4	58.0	61.9	—	58.3	66.7
A8.8—Weekly frequency of sell	105	11.3	21.2	11.8	17.0	16.2	—	21.7	8.9
% Once		64.2	73.1	58.8	70.5	68.6	—	66.7	71.1
% More than once		24.5	5.8	29.4	12.5	15.2	—	11.7	20.0
$\chi^2$		7.93*		3.20		—		3.84	
Consumption									
RU6.1—Dietary diversity	116	8.1 (1.04)	7.7 (1.76)	8.4 (1.06)	7.8 (1.50)	8.1 (1.32)	6.3 (1.79)	7.6 (1.61)	8.3 (1.10)
Produced									
$U$		1563.50		634.00		223.50 ***		1173.00**	
A8.1—Importance of crops for self-consumption	116	98.3 (7.94)	98.4 (5.12)	99.0 (3.51)	98.2 (7.06)	98.1 (6.97)	100.0 (0.0)	98.5 (5.46)	98.1 (8.10)

Table 4 (continued)

Agri-food activities & third-tier SES variables	n <sup>a</sup>	Indigenous <i>Saraguro</i>	Mestizo	RAL	Non-RAL	Marketing of agri-food products	Without marketing of agri-food products	Off-farm work	Without off-farm work
A8.2—Importance of small animals for self-consumption	113	90.5 (16.14)	91.0 (18.67)	94.1 (16.61)	90.2 (17.49)	89.9 (17.98)	100.0 (0.0)	90.26 (15.85)	91.5 (19.33)
A8.3—Importance of traditional Foods	116	13.8	19.0	11.8	17.2	15.2	27.3	19.1	12.5
		1524.50		710.00		407.00*		1428.00	
	% Low	27.6	31.0	11.8	32.3	29.5	27.3	25.0	35.4
	% Medium	56.8	50.0	76.5	50.5	55.2	45.5	55.9	52.1
	% High <sup>d</sup>	24.1	27.6	52.9	21.2	26.7	18.2	29.4	20.8
A8.4—Dependence of non-chased foods low	116	50.0	36.2	47.1	42.4	45.7	18.2	42.6	43.8
	% Medium	25.9	36.2	0.0	36.4	27.6	63.6	27.9	35.4
	% High	2.41		11.90**		6.19*		1.32	
In micronutrients	$\chi^2$								

Asterisks indicate significant differences after the non-parametric statistical tests ( $\chi^2 = \text{Chi-Square}$ ;  $U = \text{Mann-Whitney-U}$ ): m.s. (marginally significant) =  $0.05 < p < 0.1$ ; \* $p \leq 0.05$ ; \*\* $p \leq 0.01$ ; \*\*\* $p \leq 0.001$

S.D. standard deviation

<sup>a</sup>Number of respondents

<sup>b</sup>Results of bivariate analysis (statistical value) are not shown because there are not significant relationships for any of the groups analyzed and/or the bivariate analysis is not applicable

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