Agroecosystem resilience. A conceptual and methodological framework for evaluation

Cindy Córdoba[1¶], Catalina Triviño[2¶], Javier Toro[2¶*]

1. Centro Interdisciplinario de Estudios sobre Desarrollo (CIDER), Universidad de los Andes, Bogotá, Colombia
2. Instituto de Estudios Ambientales, Universidad Nacional de Colombia, Bogotá, Colombia

* Corresponding author

jjtoroca@unal.edu.co (JT), ORCID: https://orcid.org/0000-0001-6675-5148

¶These authors contributed equally to this work.

Abstract

This article proposes a conceptual and methodological framework for analyzing agroecosystem resilience, which incorporates agrarian structure and peasant community agency. The methodology is applied to a comparison of two peasant communities in Latin America (Brazil and Colombia), emphasizing the capacity to transform unsustainable power structures in place of adapting to them. This application demonstrates that when agency is strongly developed, as in the case of Brazil, it is possible to transform structural conditions that restrict resilience. The inclusion and consideration of biophysical variables, management practices, agrarian structure and agency, through a participatory approach, allows for the identification of factors that inhibit or potentiate the resilience of agroecosystems.

Key Words: Resilience, Agrarian Structure, Agency, Agroecosystem, Latin America, Methodology, Resilience Evaluation

Introduction

The concept of resilience has evolved from an ecological perspective to that of complex systems analysis. Initially, it was conceived as the capacity to confront, absorb and adapt to disturbances, without changing, in order to return to a state of normality (1,2). Resilience was calculated or evaluated depending on the amount of time it would take to return to this condition (3). Analysis and discussions in the context of socio-ecological systems challenged the idea of normality, adopting an understanding of multiple equilibriums and accepting the inevitability of change (2,4). In this sense, many proposed that resilience is systems adaptation based on learning, planning and reorganization for the purpose of preserving function, structure and identity (5–7). Still, socio-ecological systems such as agroecosystems, conceptualized from a perspective of "fully integrated system[s] of people and nature" (8), do not exhibit unique identities, functions or structures (9). Agroecosystems are systems composed of physical, biological, socioeconomic and cultural subsystems that coalesce and interact within the framework of human-led agricultural

processes (10,11). In this sense, human intervention, expressed in different interests, values and criteria, impede the determination of a unique structure and system function (9,12).

Any system involving human interaction holds power relations that can form or influence resilience (13), since these determine which groups have access to and control of resources, assume the burden of risk, and have the possibility of participation and political decision-making (14,15). Additionally, the fluctuating nature of these systems clashes with the concept of identity, which can be understood as seeking a static and invariable condition (16).

The complementary concept of resilience offered in this article is not necessarily neutral or inherently positive, due to the lack of consensus across society on the objectives and strategies for responding to or interacting with change or disturbances (17). The resilience of agroecosystems is often power-dependent. While resilience can increase through the operation of privileged groups with greater access to resources and political participation, it can also decrease under groups with less economic power (18). Therefore, it is necessary to question, resilience for whom and for what purpose? (16,19). In this study, resilience is analyzed from the perspective of peasant and rural communities in Latin America. From the point of view of the elite, resilience is understood to be adaptation to conditions of inequality and injustice, which agrees well with neoliberal (20) and Keynesian discourse, in other words, maintaining the *status quo*. On the other hand, those with less power understand resilience to be transformation conducive of conditions of justice, which can lead to the destruction of the predominant social system (1,21–24).

The purpose of this article is to present a conceptual framework and complementary methodologies for analyzing and evaluating agroecological resilience, including factors relevant to agrarian structure and peasant community agency. This approach and methodology are applied in the comparison of two rural peasant communities in Latin America (Brazil and Colombia), emphasizing the capacity to transform unsustainable power structures instead of adapting to them.

The first part of the article refers to the elements that are included in calculating resilience indicators, followed by an analysis of the reach and limitations of methodologies that have been applied in rural contexts. On this basis, a new methodology is proposed for analyzing resilience. This new methodology is then applied to two locations in Brazil and Colombia. The results are presented and discussed, followed by general conclusions.

Agrarian structure

Whenever agroecological systems are analyzed, it becomes necessary to define the agrarian structure (AS), whose nucleus is the property of the land, based on which all other economic, social, cultural and political interactions are built. This concept combines a set of factors including the size of agroecosystems, the use and control of resources, labor conditions, relationships among social actors and between social actors and the market, infrastructural aspects and other features (25,26).

In Latin America, land has been employed as an instrument of power and social domination (27,28). High levels of land concentration (called "latifundia") or small subsistence-oriented (called "minifundia") farms constitute the principal motor for the backwardness and underdevelopment of the rural sector (29–32). Since AS is transcendentally vital to productive power relations, peasant marginalization, territorial sovereignty, food production and access to dignified living conditions, it is surprising that it has not been included within analyses of resilience in the rural sector.

Land has historically been configured as a central means of production, whose appropriation and accumulation lay the groundwork for the construction of social power relations that determine the peasant population's access to resources, goods and services, is a main element of their dignity and identity, and defines a great extent of their autonomy, socioeconomic

conditions and the development of their means of livelihood. All of these factors directly impact resilience and the capacity for transformation within rural communities (33–35).

Capacity of agency

The capacity of agency is understood as the empowerment of marginalized communities to engage in collective objective-oriented action aimed at transforming societal power relations (24,36,37). Agency goes beyond resisting, buffering or adapting to the hardships of capitalism. It implies that peasants can build new paths in response to a system they consider unsustainable (2), employing their own creativity, political decision-making and organizational power, to unravel their own development processes.

The role of organized collective agency has not been integrated within analyses of resilience (37). More research is needed to include the ways in which human actions shape factors such as agrarian structure. Resilience analyses have not considered power relations, assuming the existence of a society in consensus, in which it is common for certain groups to support the disasters provoked by capitalism (17,38). Nevertheless, it is relevant to include the way in which conscious choices made collectively and individually can transform conditions of inequality towards essentially new systems, this being a fundamental factor in the level of resilience acquired (9,39,40).

In this sense the proposed methodology for evaluating resilience includes the decisions peasants make about the use of resources for agricultural production (both infrastructure and subsistence), as well as the level of organization, training and political decision-making power (18,41,42). It is relevant to incorporate a differentiated analysis, not only of the economic situation of women (pay for market-oriented work, subsistence and caregiving), but also of aspects related to their empowerment, such as the levels of organization and participation in political decision-making processes (27). The participation of women is essential because they are considered to be

128 political subjects who organize and participate in decision-making regarding economic,
129 productive, technical and political aspects, thus transforming power relations (43–47).
130

131 # Methodologies for evaluating resilience

132 There are many methodological problems and few evaluation frameworks for resilience
133 in rural contexts (39,48,49). Some methodologies are centered around ecological and productive
134 variables, employing indicators such as landscape complexity, vegetation diversity, slope and soil
135 conservation, energy efficiency, subsistence, water and soil conservation practices, input and
136 technology dependence and others (10,42,50–53). These approaches address social factors only
137 in a limited and tangential way through their general definition of resilience as the capacity of
138 communities to adapt to extreme stressors within the productive sector.
139

140 Authors such as (4,37,39), recognize that the social aspects of resilience are weakly
141 developed, especially with regards to empowerment. (54,55) include notions of collective
142 community agency as important to resilience, but they do not propose measurement instruments.
143 (56) presents eight (8) dimensions of community resilience with metrics that have not been
144 applied in practice and that are centered on the capacity to adapt to change. (57) employ official
145 statistics to propose an index of rural diversity, considering natural economic and social capital,
146 under the premise that diversity increases resilience. Other authors include, in addition to
147 ecological variables, factors such as food security, income, access to services and support
148 networks (58). These are, however, included without numerical qualifiers or variable weights.
149 Although (59) quantify variables such as land size, financial sources, credit and network
150 participation, these are limited to describing the way in which these influence the adoption of
151 agricultural technologies. (49) present 13 indicators of agroecosystem resilience which include
152 social organization, learning, local knowledge and autonomy. Nevertheless, none of these
153 variables consider social inequalities or access to land, determining factors for peasant
154 livelihoods. (60,61) introduce aspects such as social inequality and land property, recognizing

155 that the socio-cultural context limits resilience. They center their attention on the capacity of
156 farmers to respond with productive agroecological practices and define empowerment as
157 decision-making for adaptive farm management in response to disturbances.
158
159 None of these studies includes the role of peasant agency in the transformation of
160 structural factors that subvert power relations, bypassing the role of political organization and the
161 building of new pathways, not only in the productive or ecological sense, but also in the social
162 and political spheres. Productive relationships, working conditions and the use and control of
163 resources are not evidenced, neither is it specified what social group's perspective is being
164 analyzed in terms of resilience. All of this leaves unanswered the questions of resilience for what
165 end? and for whom? raised by (16). Authors that consider the transformation of the status quo
166 instead of its preservation (2,55), do not develop methodological proposals for the quantification
167 of principal variables.
168
169 Resilience is the result of complex interactions among ecosystems, economic, social and
170 cultural systems and cannot be analyzed through a fragmented consideration of each component
171 in isolation from the whole (57). With this challenge in mind, a methodology is proposed for
172 measuring resilience in rural peasant communities, through the quantification and weighing of
173 differing attributes. In addition to aspects related to AS and peasant agencies, related factors are
174 incorporated to the conditions and context in which productive activities are developed, including
175 biophysical, social and health variables, as well as practices used in agricultural production. In
176 addition, market interactions were considered, which represent the effect of variables out of the
177 peasants' control that exercise a strong impact on income level and livelihood development.
178
179 Therefore, it is necessary to present a complementary conceptual and methodological
180 framework that allows the identification of factors that support or inhibit resilience in Latin
181 American peasant communities. The complex analysis of diverse factors that constitute resilience,
182 with an emphasis on AS and the capacity of collective agency, allows for an understanding of

183 substantial aspects in need of transformation. This allows peasants to generate their own
184 development dynamics based on their own interests and needs, favors processes of empowerment
185 for implementing radical changes in the generation of public policy, access to resources and
186 capital, and potential for autonomy (62–65). In this sense resilience refers to social change and
187 challenges the *status quo* to give place to alternative scenarios (1,22,23,26).
188

189 Material and Methods

190 Proposed methodology for evaluating resilience

191 The procedure for evaluating resilience consists of three phases: (i) selection and
192 weighting of factors, criteria and variables, (ii) scoring of variables, (iii) assigning quantified
193 values to resilience.

194 Selection and weighting of variables

195 A scoring matrix was built with a hierarchical structure composed of four (4) factors,
196 eight (8) criteria and seventeen (17) variables (Fig 1). Weighting coefficients were assigned to
197 each variable, factor and criteria, through consultation with principal actors in each community
198 as well as expert opinion from several disciplines (anthropology, agroecology, health sciences,
199 environmental sciences and administration). The final values were determined in a participative
200 manner using the Delphi method (Table 1), which establishes a structured communication
201 between experts and community members who are knowledgeable of study sites, to validate each
202 category used in the analysis (66,67).
203
204 **Fig 1. Hierarchical structure for the evaluation of agroecosystem resilience**
205

206 **Table 1. Weighting matrix of factors, criteria and variables for the assessment of resilience**
207

Factor	Criteria	Variables
Capacity for agency [50]*	**Political-organizational [35]**	Pertinence and/or link to organizations, cooperatives, and educational institutions **[11.6]**
		Level of training and political decision-making power **[11.6]**
		Level of training and political decision-making power (women) **[11.6]**
	Use of resources [15]	Subsistance (animal and vegetable) * **[7.5]**
		Infrastructure **[7.5]**
Agrarian structure [38]	**Land tenure [19]**	Property size* and/or area **[9.5]**
		Land ownership **[9.5]**
	Production relationships [19]	Labor conditions **[6.3]**
		Market relationships **[6.3]**
		Level of income* **[6.3]**
Conditions and context [10]	**Biophysical factors [9.5]**	Soil quality **[1.2]**
		Distance to forests and water sources **[1.2]**
	Social factors [17]	Access paths **[2.2]**
		Access to public services and telecommunications **[2.2]**
	Health factors [11.5]	Drinking water **[1.5]**
		Frequency of protein consumption **[1.5]**
Productive practices [2]	**Soil management and biodiversity [3]**	Soil management and biodiversity **[3.0]**

208
209
210 [*] Values within brackets are proposed weights

211 # Scoring of variables

212 Data for differing variables were reported in different measurement units. For example,
213 the area of land is expressed in hectares and the level of income in currency, while other
214 characteristics are qualitative (land ownership or pertinence to organizations). Therefore, all
215 measurement units were transformed to a standard 0 to 5 scale, where 0 represents the lowest
216 level of resilience and 5 the greatest. This methodological strategy has been utilized and validated
217 in several similar studies (68–76). The values were negotiated in a participatory manner,
218 employing questionnaires, semi-structured interviews, expert opinion and literature review. Table
219 2 presents the consolidated matrix with scoring criteria.

220

221 # Quantitative assessment of resilience

222 The value of agroecosystem resilience is the result of the sum of the 17 weighted
223 variables. Where: AgRe: Agroecosystemic Resilience; Vi: Variables; Wi: Weight.

224

$$AgR_e = \sum_{i=1}^{i=17} v_{i*Wi} \quad (1)$$

225

226

227 **Table 2. Resilience scoring matrix**
228

Factor: Capacity for Agency				
Criteria	**Variable**	**Question**	**Answer**	**Score**
Organizational-political	Pertinence and/or link to organizations, cooperatives, and educational institutions	Do you pertain to or are you linked to an organization that….?	Favors the capacity of economic and political transformation of the community, favors the capacity for transformation of the agroecosystem.	5
			Favors the capacity of transformation at the agroecosystem level.	3
			Generates little or no betterment of resilience conditions.	1
	Level of training and political decision-making power	What is the level of participation in community decision-making processes (regarding technical, productive, economic or political decisions)?	High	5
			Medium	3
			Low	1
		What is the level of participation in political training meetings aimed at learning about and demanding rights?	High	5
			Medium	3
			Low	1
	Level of training and political decision-making power (women)	What is the level of participation and political organization of the women in the neighborhood or municipality?	High	5
			Medium	3
			Low	1
			Does not participate/ there is no organization	0
Use of resources	Subsistence (animal and vegetable) *	Number of animal species produced on the farm and used for subsistence	Two standard deviations above the average	5
			Two standard deviations below the mean	0
	Infrastructure	How do you rate the installations, tools for production and irrigation (if necessary) used for your main economic activity? (taking the mean of the three variables)	Very good	5
			Good	5
			Average	3
			Poor	2
			Very por	1
			Does not possess infrastructure	0

229
230

231 **Table 2 (Continuation). Resilience scoring matrix**
232

Factor: Agrarian Structure				
Criteria	**Variable**	**Question**	**Answer**	**Score**
Land Tenure	Size of land*	Area of the farm in hectares	If the size of the land>=UAF, then the score is 5, otherwise the score is calculated as (size/UAF) *5.	0-5
	Land ownership	Type of property	Landless	0
			Sharecropper	1
			Renter	2,5
			Owner (with land title)	5
			Owner with land title from a peasant organization	5
			Collective property	5
Production relationships	Labor conditions	Labor rights: Is there an established work schedule, rest period, vacation time and endowments? (averaging the 4 factors)	Yes	5
			No	0
		Do you participate in any collective productive activity in your community?	Yes	5
			No	0
		Paid family labor (principal product)	Always	5
			Occasional	3
			Never	0
		Compensation for women for jobs such as: sustenance, domestic responsibility, production for the market (averaging the 3 factors)	3 jobs	5
			2 jobs	3
			1 job	1
			Never	0
	Market relations	What is the level of decision-making power regarding product market prices?	Medium	3
			Low	1
			Nonexistent	0
	Level of income*	What is your average level of income? **	Under minimum wage (MW)	0
			(Income*5) /2 MW	3
			Over or equal to 2 MW	5

233
234

235 **Table 2 (Continuation). Resilience scoring matrix**
236

Factor: conditions and context				
Criteria	**Variable**	**Question**	**Answer**	**Score**
Biophysical factors	Soil quality	How do you rate soil fertility on your farm?	High	5
			Medium	3
			Low	1
			Not fertile	0
		Gradient on the farm	None 0°	5
			Very low 0%-5% (0-8,5°)	4
			Low 15%-30% (8,5°-16,7°)	3
			Medium 30%-50% (16,7°-26-6°)	2
			High 50%-100% (26,6°-45°)	1
			Very high >100% (45°)	0
	Distance to forests and water sources	Distance of the agroecosystem to natural forest fragments (using area geometry and spatial analysis)	High: between 0 and 300 meters.	5
			Medium: between 300 and 500 meters.	3
			Low: between 500 and 1.000 meters.	0-1
		Distance of the agroecosystem to bodies of water (using area geometry and spatial analysis)	High: between 0 and 50 meters.	5
			Medium: between 50 and 100 meters.	3
			Low: between 100 and 300 meters.	0-1
Social factors	Access paths	Principal access path from the farm to a point of sale for the main product	Paved road	5
			Combined paved road and unpaved road	4
			Unpaved road	3
			Trail	2
			Bridle path	1
			No access paths	0
	Access to public services and telecommunications	Public services (drinking water, light, household gas)	All 3	5
			2 of 3	3,3
			1 of 3	1,7
			None	0
		Communications (newspaper, telephone (cellphone signal), internet, radio, tv)	All 5	5
			4 of 5	4
			3 of 5	3
			2 of 5	2
			1 of 5	1
			None	0

237

238 **Table 2 (Continuation). Resilience scoring matrix**
239

Factor: conditions and context				
Variable		**Question**	**Answer**	**Score**
Health factors	Drinking water	Do you have access to clean drinking water?	No	0
			Si	5
	Frequency of protein consumption	Number of protein products consumed daily by every member of the family (eggs, legumes and meats)	(# times a week) /21) *5	0-5
Factor: productive practices				
Criteria	**Variable**	**Question**	**Answer**	**Score**
Soil management and biodiversity	Soil management and biodiversity	Do you use polyculture or accompanying diversity for pest control, increased soil fertility or subsistence agriculture?	No	0
			Yes	5
		How often do you use herbicides, pesticides and synthetic fertilizers?	High	0
			Medium	1
			Low	3
			None	5
		How would you rate your level of traditional knowledge and/or training in agroecology?	High	5
			Medium	3
			Low	2
			None	0

240
241 **Data were normalized, and atypical values were eliminated, then the mean and standard deviation were*
242 *calculated.*
243 ***Minimum wage salary for Colombia is: 264,67USD, and for Brazil: 264,58 USD*

244
245 # Application

246 The proposed methodological model was applied to two localities in Colombia and Brazil:
247 the municipality of Marulanda within the state of Caldas in Colombia (Lat 5º 17' 3" North, Long
248 74º 15' 48" West), and the municipality of Varzelandia within the North of Minas Gerais in Brazil
249 (Lat 15º 42' 5" South; Long 44º 1' 39" West) (Fig 2). These sites were chosen because they share
250 certain aspects such as the bimodal structure of land ownership, where "latifundia" and
251 fragmented smallholder farms are predominant, with self-sustainable agricultural family units
252 (Family Agricultural Units or UAF) and inspection units (Fiscal Modules) under the
253 recommended area (18,83 ha) by the Colombian Institute for Rural Development (Colombian
254 Institute for Rural Development or INCODER) in Colombia and the recommended area (50 ha)

by the National Institute for Colonization and Agrarian Reform (INCRA) in Brazil. This land concentration generates inequality in power relations, that should be considered when measuring resilience in rural communities. On the other hand, the marked differences between these two communities to transform their socioecological systems allows a comparison of their level of agency and how this influences the final evaluations of resilience in each case.

Fig 2. Localization of study areas

Data collection

Qualitative and quantitative methods were combined for the analysis of biophysical and sociocultural conditions that come into play in the resilience of both communities. The following data collection instruments were used:

Participatory workshops*:** 5 group workshops were conducted in the municipality of Marulanda and 8 in the municipality of Varzelandia, including main actors in each municipality. In the workshops variables and resilience scoring criteria were defined in a participatory manner. ***Surveys: surveys were conducted in each of the studied agroecosystems (N=34), employing a questionnaire composed principally of close-ended multiple-choice questions and forecasting (77).

***Semi-structured interviews*:** 23 semi-structured interviews were conducted in Marulanda and 31 in Varzelandia, with town officials, peasants, leaders of political and local organizations, which permitted a greater degree of flexibility and depth in obtaining information (78). The interviews were conducted in different workspaces of planting and harvesting, local commerce and the home.

Results, Discussion, Conclusions

In consensus, the communities of both municipalities and experts assigned a coefficient of 0.5-1.0 to the capacity for agency, since it represents an indispensable factor for the construction of resilience. Agency is directly related to the ability of the community to self-organize and strengthen autonomy and participation in decision-making spaces, generating transformations, adjustments and modifications at different scales in each social, economic, political, ecological, and livelihood context.

The factor that was given the second most important weight was agrarian structure (0.37-1.0), which consists of the size of the agroecosystem, the type of ownership and other factors derived from the first two, such as market relations, working conditions and income level. The remaining criteria, "conditions and context" and "productive practices", were given lesser relevance in the construction of resilience, since they can be modified by human agency. Therefore, they were assigned a weight of (0.1-1.0) and (0.03-1.0) respectively.

Fig 3 shows that the resilience of agroecosystems in the municipality of Marulanda, Colombia is lower than that of agroecosystems in the municipality of Varzelandia, Brazil (71%). The municipality of Marulanda had low scores (< 2.5), while the municipality of Varzelandia had average scores (2.5-3.5) for 68% of agroecosystems and high scores (> 3.5), for the remaining 18%.

Fig 3. Total values of resilience in Brazil and Colombia

The analysis of variance resulted in a confidence level of 95%, which signifies that the resilience of the municipality of Varzelandia is significantly greater than the resilience of the municipality of Marulanda, and that this result is not due to chance (79). Significant variables

include: the degree of membership in organizations, the degree of training and political decision-making power, political participation of women, infrastructure, land ownership and working conditions.

The inclusion of AS and agency criteria allows for a closer representation of reality and explains why some variables held higher ratings than others. In the case of Varzelandia, the peasants' capacity for agency modified certain aspects related to agrarian structure, for example, through the occupation and ownership of fertile lands (average score of 4.6) and flat lands (average score of 4.3), which were previously owned by powerful landowners (77% of the territory was held by 8 landowners). This factor also allowed for a transformation of productive relationships by developing a collective production area where women, youth and elderly are remunerated through hourly pay (average score of 2.2 versus 0.4 for the municipality of Marulanda). Prior to developing the collective area, the peasants in Varzelandia worked under local landowners and were often exploited. This implies that beyond adapting, they managed to transform structural conditions, enhancing their resilience. In addition, the capacity of organization and community-level management created enough pressure for the Mayor and city council to provide materials and machinery for the construction of a deep well and bridge over the river Arapuim, thus improving the infrastructure score (3.6 versus 2.7 for the municipality of Marulanda). In addition, the community committed itself to facilitating labor for these two projects, carrying out the process collectively. The installation of the deep well guarantees irrigation for the collective production area, and the construction of the bridge improves connectivity, transport and quality of life.

On the contrary, in the municipality of Marulanda, the community adapted to social conditions without achieving transformations that would improve peasant livelihoods. Therefore, in general, the score for pertaining to or connecting with organizations or cooperatives (average 2.7), as well as the degree of training and family-level political decision-making power (average 1.0) and especially women's decision-making power (average 1.0), was low in all cases. In this

336 municipality, the peasant smallholder has restricted access to resources, goods and services, and
337 productive activities use unpaid family labor intensively, in order to increase their precarious
338 income and improve living conditions. It is evident in this case that simple commodity production,
339 developed individually, limits the accumulation of capital (80,81).
340
341 Socio-economic conditions influence community agency. In the municipality of
342 Varzelandia, the deep history of land struggles and strong peasant organization has allowed
343 farmers to solve problems related to land tenure and production relationships. However, in the
344 municipality of Marulanda, the historical absence of land struggles has maintained a limited
345 division of land parcels through informal agreements, perpetuating the dominant economic
346 position of powerful landowners (80).
347
348 Factors at all scales affect the resilience of the agroecosystem. For example, peasants have
349 no impact on the prevailing factors governing market relations, and therefore, market relations
350 are scored as zero in both municipalities, regardless of the capacity for agency. The fixing of
351 product prices is determined by various dynamics of the capitalist market and by local economic
352 powers (82).
353
354 Dependence on the country's agricultural policies or international fluctuation of prices
355 negatively affect resilience (2,83). Therefore, it is necessary to include power relations derived
356 from global scales, which prevent peasants from reaching full autonomy in decision making or
357 real participation in processes of political definition (8,16,19,84).
358
359 Weighing criteria and landscape indicators give a closer sense of the reality of the case
360 studies and allows a greater understanding of the factors that most strongly affect resilience.
361 Without weighing variables, certain factors such as soil fertility, slope or access to public services
362 would be considered on an equal level as criteria related to community agency or agrarian
363 structure. The proposed methodology includes aspects that are normally invisible, revealing

364 power relations and transformation processes that alter structures and predominant social
365 dynamics within communities (21,85).
366
367 Fig 4 shows the results of calculating resilience without considering AS or agency,
368 utilizing criteria associated with productive practices and biophysical conditions in comparison
369 with the weighted average using all the proposed variables. The results of the municipality of
370 Marulanda are higher in scenario Y than scenario X, with a variance between 18 and 93%. On the
371 contrary, the municipality of Varzelandia showed lower results for scenario Y, lowering the mean
372 values of resilience, with soil fertility and slope being the variables with the greatest weight.
373
374 **Fig 4. Total resilience in Brazil and Colombia comparing all proposed variables (scenario**
375 **X) vs. only biophysical factors and management practices (scenario Y)**
376
377 When only biophysical factors and agricultural practices are considered, there is only a
378 difference of 0.2% between the two localities (a score of 2.7 for Colombia vs. 2.5 for Brazil). On
379 the contrary, when all variables are considered, the difference between average values is almost
380 a whole point (1.0), with Brazil showing the greater average score.
381
382 The values with the highest scores in the municipality of Marulanda were distance to
383 forests and water sources (average 4.4 vs. 1.0 in Varzelandia) as well as the presence of rivers
384 and water sources within ecosystems (1.5 vs. 0.1). In this sense it would be difficult to adopt
385 strategies to increase resilience, since the criteria are already a part of the environment in which
386 the agroecosystems are immersed and therefore difficult to modify.
387
388 Including all variables allows for an evaluation and analysis that can be used as an
389 instrument to support decision-making in the short, medium and long term, as well as a tool for
390 planning and determining effective solutions in the social sphere (86,87). The transformations
391 peasants require to increase their resilience involve power structures, markets, institutions and

392 predominate societal values (83,84). Beyond the biophysical factors and productive practices,
393 rural populations are immersed in social contexts, within which they are challenged by political
394 and economic differences, not only at the local scale but also at the global scale (16,18,88).
395

396 # Conclusions

397 The findings reveal that the level of political organization and participation in decision-
398 making processes regarding economic, productive, technical and political components of
399 agroecosystems, as well as the acknowledgement of rights and the determination to organize to
400 demand them, are factors that favor the transformation of structural aspects in the municipality of
401 Varzelandia. Therefore, the capacity of agency received a greater weight in the overall
402 quantification of resilience.
403

404 Our attention should not only be focused on the local population's capacities to transform
405 their conditions while understating the importance of the political, social and economic context
406 that conditions these capacities. Conducts, values and the distribution of risks and benefits are
407 formed by structures and social norms. Both factors are decisive in analyzing resilience.
408

409 The peasants of Marulanda have adapted to many circumstances without achieving
410 transformation, while the peasants of Varzelandia have built effective social networks,
411 strengthening their capacity for agency and transformation before conditions of social inequality.
412

413 The proposed methodology can be replicated in other contexts, including other
414 indicators and weights that represent what is valued by a society, along with its knowledge and
415 perceptions.
416

417 The proposed resilience is directed towards the formulation of strategies and policies
418 aimed at inducing radical change at the local and regional level. In this way it cannot be

constrained by access to technology or biophysical resources that favor adaptation and a limited sense of wellbeing for peasant communities.

Funding

This paper gratefully acknowledges the support and funding from Interdisciplinary Center for Development Studies, Universidad de los Andes (Bogotá, Colombia) and the project: "Environmental Impact Assessment in Colombia. Critical analysis and Improvement", Code Hermes: 13129, Universidad Nacional de Colombia, sede Bogotá.

References

1. Martin-Breen P, Anderies J. Resilience: a literature review [Internet]. Newark, NJ: Institute of Development Studies (IDS), the Resource Alliance and the Rockefeller Foundation; 2011. Available from: https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/3692/Bellagio-Rockefeller bp.pdf?sequence=1&isAllowed=y
2. Walker B, Holling C, Carpenter S, Kizing A. Resilience, adaptability and transformability in social-ecological systems. Ecol Soc. 2004;9(2).
3. Holling C. Engineering within ecological constraints. Washington, D.C.: National Academies Press; 1996.
4. Berkes F, Folke C. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge UK: Cambridge University Press; 1998. 437 p.
5. Joseph J. Resilience as embedded neoliberalism: a governmentality approach. Resilience. 2013;1(1):38–52.
6. Carpenter S, Walker B, Anderies J, Abel N. From metaphor to measurement: resilience of what to what? Ecosystems. 2001;4(8):765–81.
7. Manyena SB. The concept of resilience revisited. Disasters. 2006 Dec;30(4):434–50.

8. Cumming G. Spatial resilience in networks. In: Spatial Resilience in Social-Ecological Systems. Cape Town: Springer; 2011. p. 121–42.

9. Davies J, Robinson LW, Ericksen PJ. Development Process Resilience and Sustainable Development: Insights from the Drylands of Eastern Africa. Soc Nat Resour. 2015;28(3):328–43.

10. León T, Toro J, Martínez F, Cleves A. The main agroecological structure (MAS) of the agroecosystems: concept, methodology and applications. Sustainability. 2018;10(3131):1–21.

11. Faden R, Beauchamp T, King N. A history and theory of informed consent. Oxford: Oxford University Press; 1986. 392 p.

12. Ute K, Rhys K. Resilience, solidarity, agency – grounded reflections on challenges and synergies. Resilience. 2017;5(1):10–28.

13. Pratt C, Kaly U, Mitchell J. Manual: how to use the environmental vulnerability index (EVI). SOPAC technical report 383 [Internet]. 2004. Available from: http://islands.unep.ch/EVI Manual.pdf

14. Granderson A. Making sense of climate change risks and responses at the community level: A cultural-political lens. Clim Risk Manag. 2014;3:55–64.

15. Ensor J, Park S, Hoddy E, Ratner B. A rights-based perspective on adaptive capacity. Glob Environ Chang. 2015;31:38–49.

16. Friend R, Moench M. What is the purpose of urban climate resilience? Implications for addressing poverty and vulnerability. Urban Clim. 2013;6:98–113.

17. Hatt K. Social Attractors: A Proposal to Enhance “Resilience Thinking” about the Social. Soc Nat Resour. 2013;26(1):30–43.

18. Béné C, Godfrey R, Newsham A, Davies M. Resilience: new utopia or new tyranny? reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes [Internet]. Brighton; 2012. (IDS Working Paper). Report No.: 405. Available from: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.2040-0209.2012.00405.x

19. Lebel L, Anderies J, Campbell B, Folke C, Hatfield-Dodds S, Hughes T, et al. "Governance and the Capacity to Manage Resilience in Regional Social-Ec" by L. Lebel, J. M. Anderies et al. Ecol Soc [Internet]. 2006;11(1):19. Available from: http://www.ecologyandsociety.org/vol11/iss1/art19/

20. Bohle HG, Etzold B, Keck M. Resilience as agency. Int Hum Dimens Program Updat. 2009;2:8–13.

21. Sinclair K, Rawluk A, Kumar S, Curtis A. Ways forward for resilience thinking: lessons from the field for those exploring social-ecological systems in agriculture and natural resource management. Ecol Soc. 2017 Nov;22(4):art21.

22. Hahn T, Nykvist B. Are adaptations self-organized, autonomous, and harmonious? Assessing the social–ecological resilience literature. Ecol Soc. 2017;22(1):12.

23. Matarrita D, Trejos B, Qin H, Joo D, Debner S. Conceptualizing community resilience: revisiting conceptual distinctions. Community Dev. 2017;48(1):105–23.

24. Pelling M, Manuel-Navarrete D. From resilience to transformation: the adaptive cycle in two mexican urban centers. Ecol Soc [Internet]. 2011;16(2):11. Available from: https://www.jstor.org/stable/pdf/26268885.pdf?refreqid=excelsior%3A2407e6126fa5e7b66d9fea8cc271b1ec

25. Arroyo M. On the Concept of Agrarian Structure (Sobre el Concepto de Estructura Agraria). Rev Geográfica [Internet]. 1990;112:141–52. Available from: https://www.jstor.org/stable/40992622

26. Altieri M, Toledo V. The agroecological revolution in Latin America: Rescuing nature, ensuring food sovereignty and empowering peasants. J Peasant Stud. 2011;38(3):587–612.

27. OXFAM. Unearthed: land, power and inequality in Latin America [Internet]. Oxford; 2016. Available from: www.oxfam.org

28. Gómez S. The land market in Latin America and the Caribbean: concentration and foreignization [Internet]. Soto F, Gómez S, editors. Santiago: Food and Agriculture Organization of the United Nations-FAO; 2014. 128 p. Available from:

http://www.fao.org/3/a-i4172e.pdf

29. Barrientos-fuentes J, Torrico-albino J. Socio-economic perspectives of family farming in South America : cases of Bolivia, Colombia and Peru. Agron Colomb. 2014;32(2):266–75.

30. Keswell M, Carter M. Poverty and land redistribution. J Dev Econ [Internet]. 2014;110:250–61. Available from: http://dx.doi.org/10.1016/j.jdeveco.2013.10.003

31. Oyvat C. Agrarian structures, urbanization, and inequality. World Dev [Internet]. 2016;83:207–30. Available from: http://dx.doi.org/10.1016/j.worlddev.2016.01.019

32. Barraclough S, Domike A. Agrarian structure in seven latin american countries. Land Econ. 1966;42(4):391–424.

33. Adger WN. Social and ecological resilience: Are they related? Prog Hum Geogr. 2000;24(3):347–64.

34. Berkes F. Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. Nat Hazards. 2007;41(2):283–95.

35. Mayunga JS. Understanding and applying the concept of community disaster resilience: a capital-based approach. In: Summer Academy for Social Vulnerability and Resilience Building [Internet]. Munich, Germany; 2007. p. 1–16. Available from: https://www.u-cursos.cl/usuario/3b514b53bcb4025aaf9a6781047e4a66/mi_blog/r/11._Joseph_S._Mayunga.pdf

36. Béné C, Newsham A, Davies M, Ulrichs M, Godfrey-Wood R. Review article: resilience, poverty and development. J Int Dev. 2014;26(5):598–623.

37. Davidson D. The Applicability of the Concept of Resilience to Social Systems: Some Sources of Optimism and Nagging Doubts. Soc Nat Resour. 2010;23(12):1135–49.

38. Kolers A. Resilience as a political ideal. Ethics, Policy Environ. 2016 Jan;19(1):91–107.

39. Berkes F, Ross H. Community resilience: toward an integrated approach. Soc Nat Resour. 2013;26(1):5–20.

40. Gunderson L, Carpenter S, Folke C, Olsson P, Peterson G. Insight, part of a special feature on exploring resilience in social-ecological systems water RATs (resilience,

adaptability, and transformability) in lake and wetland social-ecological systems. Ecol Soc. 2006;11(1):16.

41. Norberg J, Cumming G. Complexity theory for a sustainable future [Internet]. New York: Columbia University Press; 2008. 315 p. Available from: https://cup.columbia.edu/book/complexity-theory-for-a-sustainable-future/9780231134613

42. Altieri M, Funes-Monzote F, Petersen P. Agroecologically efficient agricultural systems for smallholder farmers: Contributions to food sovereignty. Agron Sustain Dev. 2012;32(1):1–13.

43. Adger N. Social capital, collective action, and adaptation to climate change. Econ Geogr. 2003;79(4):387–404.

44. Coulthard S. Can we be both resilient and well, and what choices do people have? incorporating agency into the resilience debate from a fisheries perspective. Ecol Soc. 2012;17(1):4.

45. Long N, Van der Ploeg J. Heterogeneity, actor and structure: towards a reconstitution of the concept of structure. In: Rethinking Social Development Theory, research and practice. Harlow: Longman; 1994. p. 62–89.

46. Osbahr H. Building resilience: adaptation mechanisms and mainstreaming for the poor [Internet]. Oxford; 2007. Available from: http://hdr.undp.org/sites/default/files/osbahr_henny.pdf

47. Ostrom E, Burger J, Field C, Norgaard R, Policansky D. Revisiting the commons: local lessons, global challenges. Science (80-). 1999;284(5412):278–82.

48. Darnhofer I, Fairweather J, Moller H. Assessing a farm's sustainability: Insights from resilience thinking. Int J Agric Sustain. 2010;8(3):186–98.

49. Cabel J, Oelofse M. An indicator framework for assessing agroecosystem resilience. Ecol Soc. 2012;17(1):1–18.

50. Altieri M. Agroecology: the science of natural resource management for poor farmers in marginal environments. Agric Ecosyst Environ. 2002;93:1–24.

559 51. Casimiro L, Casimiro J. How to make prosperous and sustainable family farming in
560 Cuba a reality. Elem Sci Anthr. 2018;6:1–15.
561 52. Koohafkan P, Altieri M, Holt E. Green agriculture: foundations for biodiverse, resilient
562 and productive agricultural systems, International Journal of Agricultural Sustainability.
563 Int J Agric Sustain. 2011;10(1):61–75.
564 53. Sarandón S, Flores C, Gargoloff A, Blandi M. Analysis and evaluation of
565 agroecosystems: construction and application of indicators. In: Sarandón S, Flores C,
566 editors. Agroecology: theoretical bases for the design and management of sustainable
567 agroecosystems [Internet]. La Plata, Argentina: Editorial de la Universidad de La Plata;
568 2014. p. 375–410. Available from: http://sedici.unlp.edu.ar/handle/10915/37280
569 54. Brown K, Westaway E. agency, capacity, and resilience to environmental change:
570 lessons from human development, well-being, and disasters. Annu Rev Environ Resour.
571 2011;36(1):321–42.
572 55. Wilson G. Community resilience and environmental transitions. 1st ed. London:
573 Routledge; 2012. 240 p.
574 56. Magis K. Community resilience: an indicator of social sustainability. Soc Nat Resour.
575 2010;23(5):401–16.
576 57. Quaranta G, Salvia R. An index to measure rural diversity in the light of rural resilience
577 and rural development debate. Eur Countrys. 2014;6(2):1–18.
578 58. Tambo J, Abdoulaye T. Climate change and agricultural technology adoption: the case
579 of drought tolerant maize in rural Nigeria. Mitig Adapt Strateg Glob Chang.
580 2012;17(3):277–92.
581 59. Peredo S, Vela M, Jiménez A. Determination of resilience/vulnerability levels of urban
582 agroecology initiative in the south west of Andalusia. IDESIA [Internet]. 2016;34(2):5–
583 13. Available from: https://scielo.conicyt.cl/pdf/idesia/v34n2/aop0316.pdf
584 60. Gazzano I, Altieri M, Achkar M, Burgueño J. Holistic risk index: a case study of cattle
585 producers in the protected area of farrapos estuaries-Uruguay. Agroecol Sustain Food
586 Syst. 2015;39(2):209–23.

587 61. Panpakdee C, Limnirankul B. Indicators for assessing social-ecological resilience: A
588 case study of organic rice production in northern Thailand. Kasetsart J Soc Sci.
589 2018;39(3):414–21.
590 62. Bristow G, Healy A. Regional resilience: an agency perspective. Reg Stud.
591 2014;48(5):923–35.
592 63. Brown K. Global environmental change i: a social turn for resilience? Prog Hum Geogr.
593 2014;38(1):107–17.
594 64. Korzilius H. Researching resilience: some methodological is ssues. Syst Res Behav Sci.
595 2017;34(4):463–8.
596 65. Mier y Terán Giménez Cacho M, Giraldo O, Aldasoro M, Morales H, Ferguson B,
597 Rosset P, et al. Bringing agroecology to scale: key drivers and emblematic cases.
598 Agroecol Sustain Food Syst [Internet]. 2018;42(6):637–65. Available from:
599 https://doi.org/10.1080/21683565.2018.1443313
600 66. Skeiker K, Ghani B. Advanced software tool for the creation of a typical meteorological
601 year. Energy Convers Manag. 2008;49(10):2581–7.
602 67. Lee Y, Altschuld J, Hung H. Practices and challenges in educational program evaluation
603 in the Asia-Pacific region : Results of a Delphi study. Eval Program Plann. 2008;31:368–
604 75.
605 68. Arrieta G, Requena I, Toro J, Zamorano M. Adaptation of EVIAVE methodology for
606 monitoring and follow-up when evaluating the environmental impact of landfills.
607 Environ Impact Assess Rev. 2016;56:168–79.
608 69. Dee N, Baker J, Drobny N, Duke K, Whitman I, Fahringer D. An environmental
609 evaluation system for water resource planning. Water Resour Res. 1973;9(3):523–35.
610 70. Glasson J, Therivel R, Chadwik A. Introduction to environmental impact assessment. 4th
611 ed. Built Environment, Environment and Sustainability. London: Routledge; 2012. 416
612 p.
613 71. Lohani B, Evans J, Everitt R, Ludwig H, Carpenter R, Tu S-L. Environmental impact
614 assessment for developing countries in Asia [Internet]. Vol. 1 Overview, Asian

615 Development Bank. Metro Manila: Asian Development Bank; 1997. 356 p. Available
616 from: https://www.adb.org/publications/environmental-impact-assessment-developing-
617 countries-asia
618 72. Ortolano L, Shepherd A. Environmental impact assessment: challenges and
619 opportunities. Impact Assess. 1995;13(1):3–30.
620 73. Phillips J. The geocybernetic assessment matrix (GAM). A new assessment tool for
621 evaluating the level and nature of sustainability or unsustainability. Environ Impact
622 Assess Rev. 2016;56:88–101.
623 74. Solomon R, Colbert B, Hansen W, Richardson S, Center L, Vlachos E. Water resources
624 assessment methodology (WARM). Impact assessment and alternative evaluation
625 [Internet]. 1977. Available from: https://apps.dtic.mil/dtic/tr/fulltext/u2/a036677.pdf
626 75. Martínez F, Toro J, León C. A complex network approach to environmental impact
627 assessment. Impact Assess Proj Apprais. 2018;1–14.
628 76. Toro J, Requena I, Duarte O, Zamorano M. A qualitative method proposal to improve
629 environmental impact assessment. Environ Impact Assess Rev. 2013 Nov;43:9–20.
630 77. Benedetti R, Bee M, Espa G, Piersimoni F. Agricultural Survey Methods. New York:
631 John Wiley and Sons; 2010. 395 p.
632 78. Galletta A. Mastering the semi-structured interview and beyond: from research design to
633 analysis and publication. New York: New York University Press; 2012. 284 p.
634 79. Fisher R. Statistical methods for research workers. Edinburgh: Oliver & Boyd; 1925.
635 80. Murillo-Lozano M. Colombian coffee culture in the XXI century: a revision to resent
636 literature. Gestión y Región [Internet]. 2010;(9):127–52. Available from:
637 http://biblioteca.ucp.edu.co/ojs/index.php/gestionyregion/article/view/942/892
638 81. Marx K. Der achtzehut brumaire des Louis Napoleon [Internet]. Vol. 1, Die revolution.
639 New York: Joseph Weydemeyer; 1952. Available from:
640 https://www.marxists.org/archive/marx/works/1852/18th-brumaire/index.htm
641 82. Lanka S, Khadaroo I, Böhm S. Agroecology accounting: biodiversity and sustainable
642 livelihoods from the margins. Accounting, Audit Account J. 2017;30(7):1592–613.

643 83. Darnhofer I. Resilience and why it matters for farm management. Eur Rev Agric Econ.
644 2014;41(3):461–84.
645 84. Pahl-Wostl C. A conceptual framework for analysing adaptive capacity and multi-level
646 learning processes in resource governance regimes. Glob Environ Chang.
647 2009;19(3):354–65.
648 85. Walker B, Salt D. Resilience thinking: sustaining ecosystems and people in a changing
649 world. Washington, USA: Island Press; 2006.
650 86. Belacel N. Multicriteria assignment method PROAFTN: Methodology and medical
651 application. Eur J Oper Res. 2000;125(1):175–83.
652 87. Hajkowicz S, Collins K. A review of multiple criteria analysis for water resource
653 planning and management. Water Resour Manag. 2006;21(9):1553–1566.
654 88. Koppel J. A multiple knowledge approach for adaptation to environmental change:
655 lessons learned from coastal Louisiana's tribal communities. J Polit Ecol. 2014;21(1):61.
656

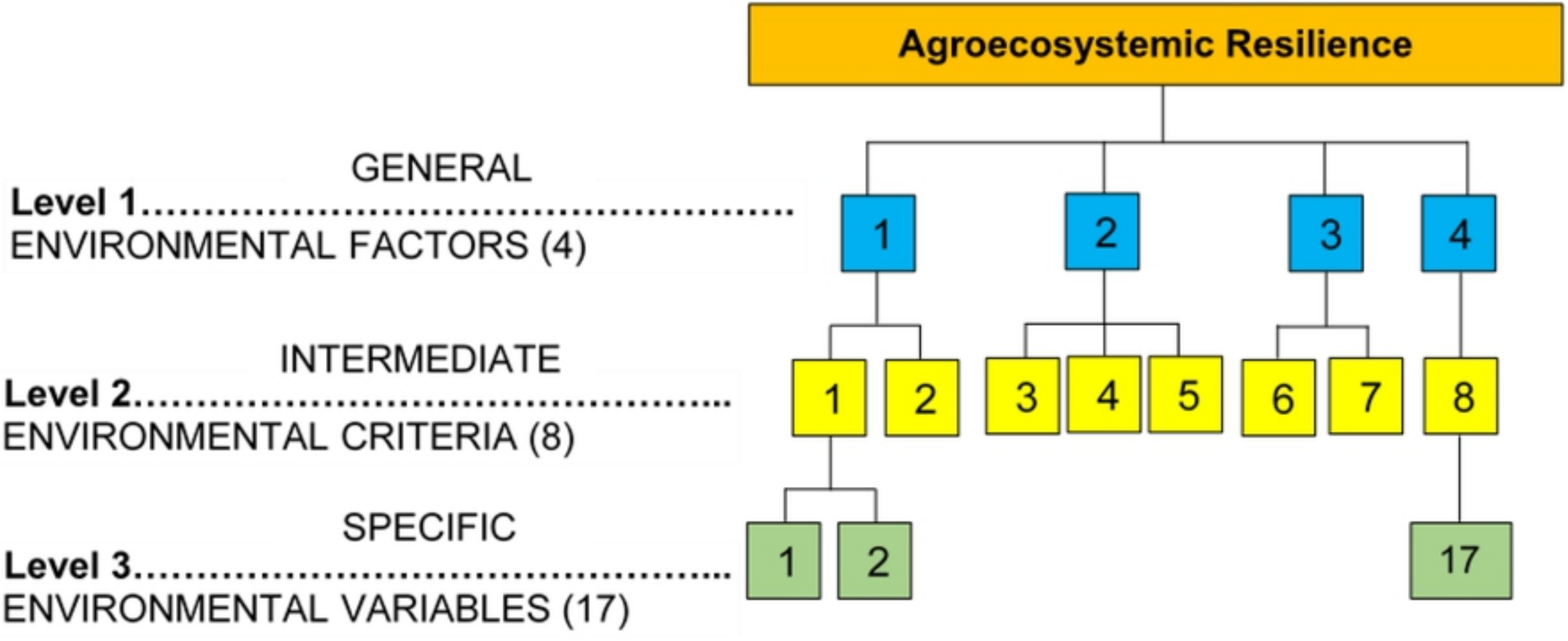
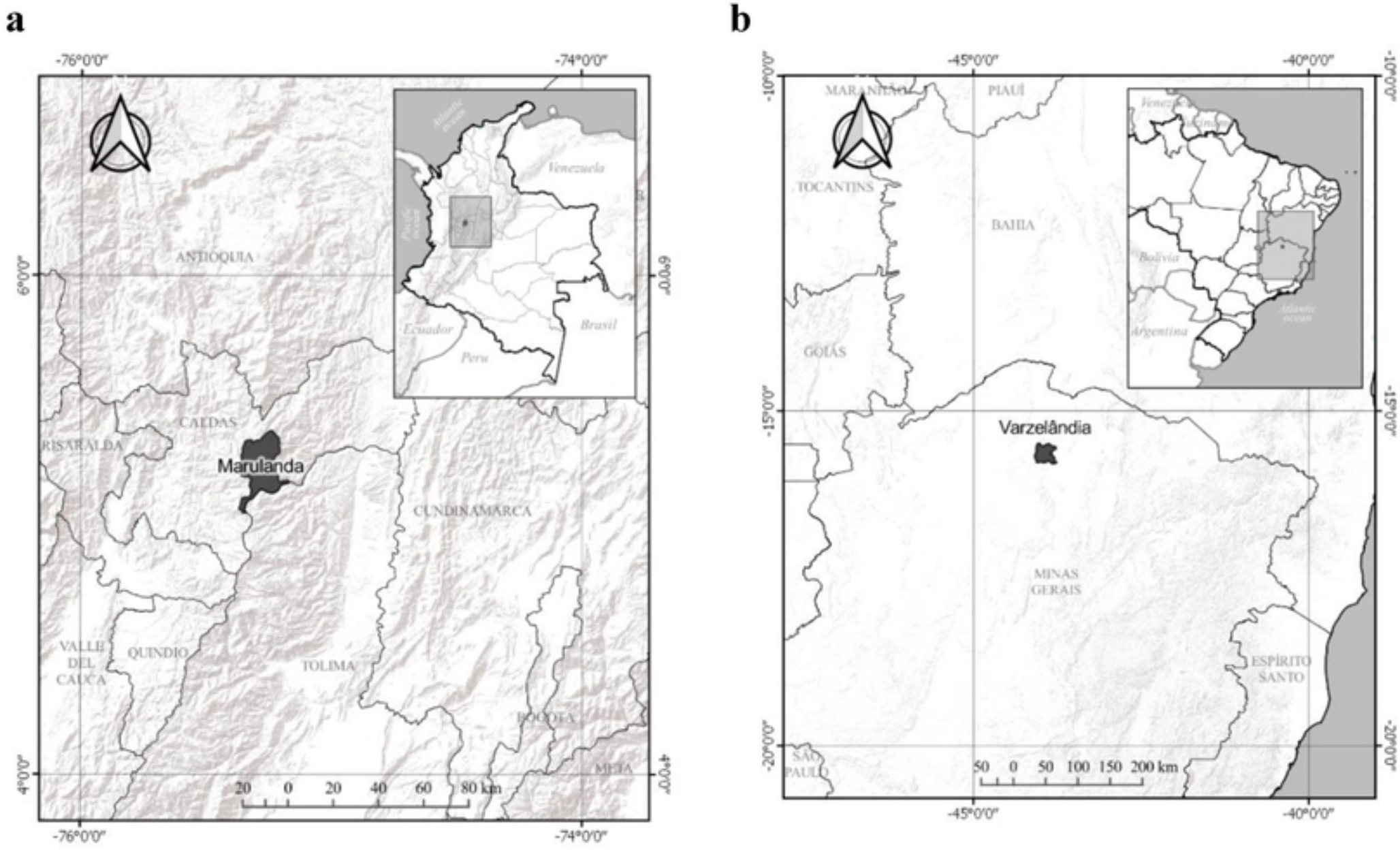
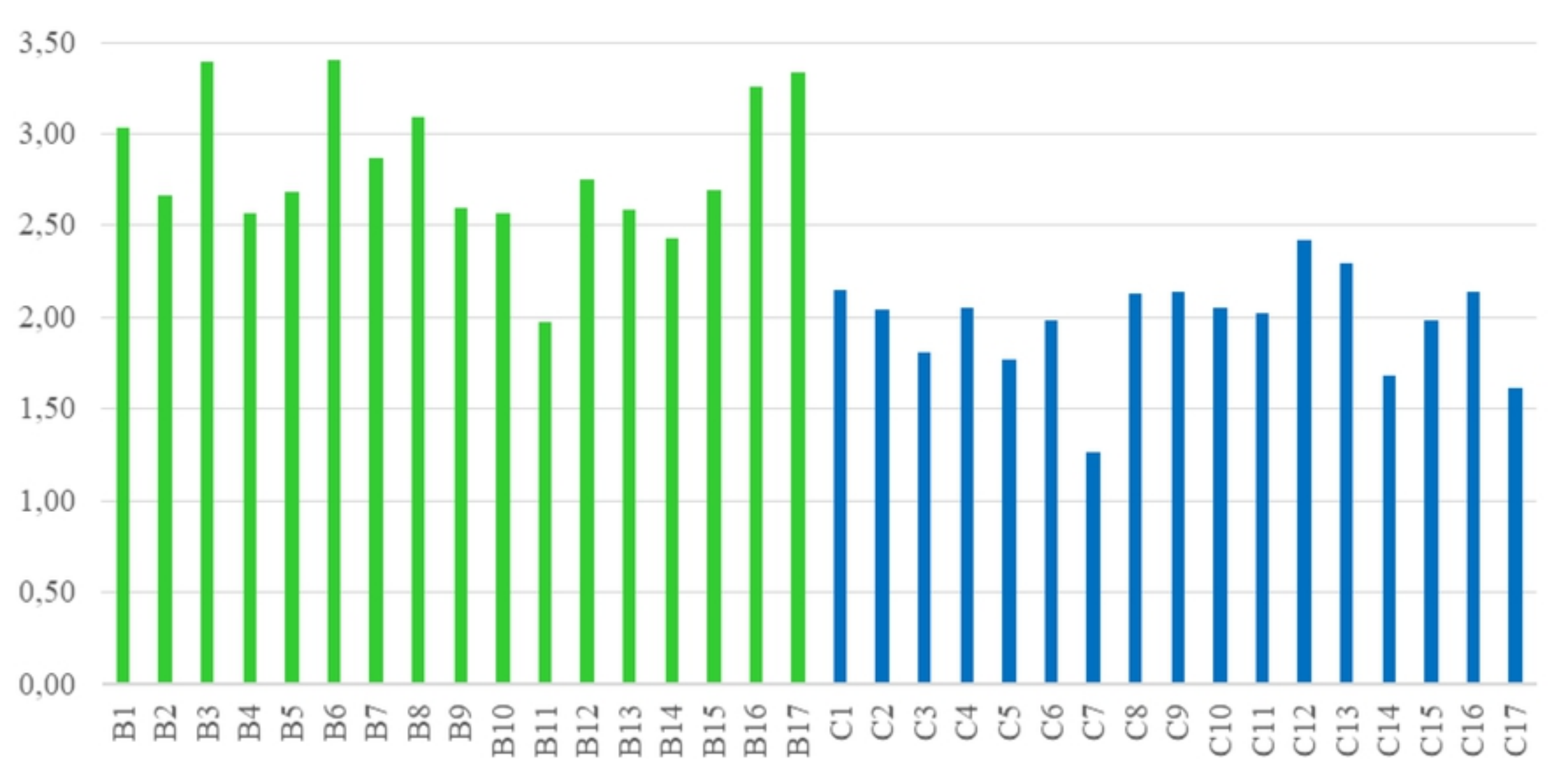

Agroecosystemic Resilience
GENERAL
Level 1.....
ENVIRONMENTAL FACTORS (4)
INTERMEDIATE
Level 2.....
ENVIRONMENTAL CRITERIA (8)
SPECIFIC
Level 3.....
ENVIRONMENTAL VARIABLES (17)
1
2
3
4
1
2
3
4
5
6
7
8
1
2
17

Figure 1.tif



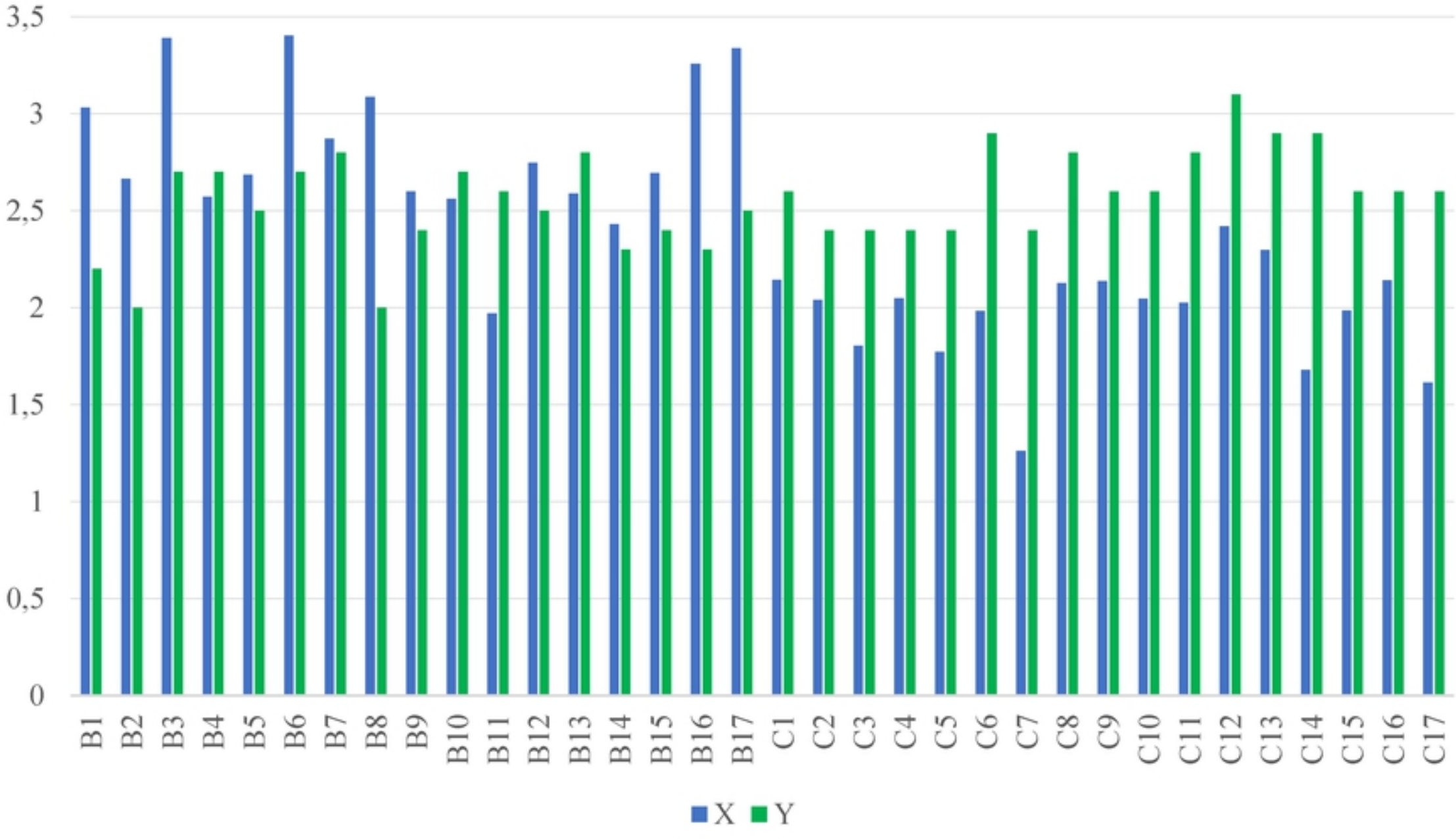
a. Municipality/Town of Marulanda, Departament/State of Caldas, Colombia
b. Municipality/Town of Varzelandia, Department/State of Minas Gerais, Brazil

Figure 2.tif



B: Brazil. **C**: Colombia

Figure 3.tif



X: Weighted mean of all proposed variables Y: Mean of biophysical variables and management practices

Figure 4.tif