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Climate Change Resilience of Smallholders on Guatemala Highlands

Michele Bruni[1] and Fabio Maria Santucci[2*]

[1]Inspira Farms Technical Director Sevenoaks, United Kingdom.
[2]Applied Economics Unit, University of Perugia, DSA3, Borgo XX Giugno 74, 06126, Perugia, Italy.

Authors' contributions

This work was carried out in collaboration between both authors. Author MB was responsible for the field work, data collection and elaboration. Author FMS supervised the research design and the data analysis. The literature search, the questionnaire design and the elaboration of the text has been a joint responsibility.

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ABSTRACT

Aims: The study assesses the resilience of smallholders against future climatic shocks, through the identification of different clusters of smallholders, and their awareness and behavior about climate change.
Study Design: The study has used a combination of qualitative and quantitative methods.
Place and Duration of Study: The field part of the study took place during the months April – August 2010, while the data entry and statistical analysis were realized in the following months.
Methodology: The field work begun in April 2010 with visits to the area, focus groups and semi-structured interviews with farmers and key witnesses; six communities in two provinces were selected; in each community, 20 farmers were chosen, for a total of 120 interviews; a first questionnaire was validated through nine interviews; the improved version, with 80 questions, was submitted during July and August 2010, but only 28 questions have been retained for this study, being the other 62 of extremely technical nature; digital codification and data entry took place in September – October 2010; statistical analysis was realized with SAS version 9.1 in the following months.

**Corresponding author: E-mail: fabiomaria.santucci@unipg.it;*

Results: Landholding size averages only 0.27 hectares, ranging from 0.04 to 1.6; 85.8% of respondents had some education, 67.5 access to water and sanitation; 51.67 do not implement any soil protection practice; 88.33% however apply some crop rotation and 87.29 follow a sowing plan. 58.33% sell to the same processing firm, but 69.17% have no certification. 63.33% have access to credit, and 55.83% to some advice. Latent Class Analysis has been implemented twice: the first one has defined two clusters along human capital and the second one three clusters along climate change perceptions. In the first case, the groups are defined Small Unskilled (77.18%) and Medium Skilled (22.82%); in the second case the groups are defined Medium Resilient Aware (68,5%), Medium Adaptive Aware (21.74%) and Small Vulnerable Unaware (9.74%).

Conclusion: Even within a seemingly quite homogeneous society, there are diverse clusters of farmers, with different assets, behaviors, agronomic management and relationships to the market. The better off, in terms of land size, human capital and income, perceive the climate change and its connected risks more than the very small ones, who manage tiny parcels and have very limited contacts with the market and extension/training. In all cases, to increase resilience and to prevent further degradation of the natural resources, a combination of public and private interventions are needed.

Keywords: Resilience; human capital; value chain approach; latent class analysis.

1. INTRODUCTION

All over the world, small-scale farming systems face an increasing vulnerability that can affect from the farm level to more systemic levels, as recently highlighted [1]. [2], because smallholders are not only producing for themselves or for local markets, but they are also increasingly integrated into supply chains for national and international markets [3].

Demographic growth, pressure on land and agricultural intensification have led in many places to soil depletion and erosion, undermining the sustainability of rural livelihoods [4]. The concept of resilience can be applied to households as well as to social systems, in order to assess vulnerability to food insecurity, interpreted as the opposite of resilience [5]. Most intervention models deal with measures for producers, but adaptation strategies [6] might also examine behaviors and assets – two key attributes for adaptive capacities. Furthermore, within the framework of resilience, the behaviors and awareness level should be assessed to determine the ability of the households and communities to cope with climate and market shocks, and even adapt creatively and proactively [7,8].

Ninety percent of the 570 million farms worldwide are managed by an individual or a family, and rely mainly on family labor, who produce more than 80 percent of the world's food, in terms of value. Eighty-four percent of these holdings are smaller than two hectares and manage only 12 percent of all agricultural land [9]. Their access to inputs, credit, extension and to markets is difficult and sometimes almost impossible, due to infrastructural problems. On the other hand, over the long period, the economic sustainability of domestic and international trade of agricultural commodities depends on the protection of the long-term productivity of natural resources, such as soil, water, and vegetation, which can only be achieved if all value chains actors, small and large, understand the problems and share a common commitment [3].

In Guatemala 34.5 percent of arable land is degraded. According to different scenarios, by 2030 the likely reduction in superficial water can be estimated between 10 and 50 percent. Accompanied by temperature increase, this will result in a lower water supply for irrigation and will lead to yield decreases: -34 percent for corn, -66 percent for beans in some areas. Households in the Highlands count on a scarcely diversified mix of rural activities comprising mainly subsistence and commercial agriculture, waged agricultural work; secondarily artisanal production of non-tradable goods (clothing, etc.), firewood collection, etc. In some areas, new forms of aggregation are appearing, to supply export markets through contract farming and fair trade approaches [10].

According to the "livelihoods profiling" of the area, inhabitants depend 100% on agricultural wages for income and 95% on the market to purchase staple foods such as corn and black beans; many migrate internally and seasonally

for coffee and corn harvest, or more permanently to the US and to the national capital city [11]. Women and children represent about 2/3 of the agricultural workforce. The diet of the poorest families in the Highlands is mainly constituted by corn and beans, while the better off consume more vegetables, fruits and additionally eggs and poultry. Corn is the main crop in the traditional system, which provides, due to the very small cultivable area available to most families, an insufficient output to feed the family for the whole year. The most vulnerable livelihoods are affected by reduced yields and employment in the Highlands and by reduced employment in the lower valley. Landslides are increasing in frequency and severity. Quite often crops and agricultural land are covered with unfertile material, hundreds of hectares are lost due to extreme events. Due to all these reasons, several projects in recent years have tried to support the organization of the communities, the introduction of new crops like the broccoli, for the domestic and foreign markets. This action has been accompanied by awareness raising activities and training.

2. MATERIALS AND METHODS

This research is part of a much wider study [1], that has analyzed resources, attitudes, perceptions, agricultural techniques, incomes, etc. of two comparable groups of very small farmers in the Guatemala Highlands, producing and trading the same commodity (broccoli) for the export market, under two different business models [12]: 480 families associated in marketing cooperatives and 3,000 households independently producing under contract farming. The marketing cooperatives manage important functions, such as the production of inputs (seedlings and organic fertilizer), as well as post-harvest value addition and factoring, whereas in the contract farming model these functions are concentrated with the food processor. The research was carried out in the Departments of Chimaltenango and Sololá, which can be considered representative of the Highlands.

An initial analysis of the farming system was carried out through eight field visits, focus groups, and semi structured interviews to farmers, to gather understanding of the structure of the smallholders' models and to refine the analysis of the value chain [13]. The communities were randomly selected from a list fulfilling several criteria: a) representativeness of the most frequent agro-bio-climatic traits (altitude and distance from main roads) of the Highlands; b) demographics and poverty, and c) experiences with non-traditional export crops. Statistical indicators for the selection were provided from the databases of the Guatemalan Ministry of Agriculture (MAGA) and of ENCOVI (Encuesta Nacional de Condiciones de Vida), the National Livelihood Survey, performed every five years by the National Institute of Statistics. The reduced dimension of the communities helped greatly to reduce the difficulties and biases for the randomized sample of households to be interviewed. The interviews were structured around four dimensions: a) value chain relationships, including relevance of smallholder sourcing, b) smallholders and agricultural challenges, c) climate change adaptation, and d) governance, policy and investment.

The first draft of the questionnaire was prepared in June 2010 in collaboration with CIAT (Centro Internacional de Agricultura Tropical), the International Center for Tropical Agriculture. It was tested and validated during the last week of June 2010, with three communities for a total of nine tests. After the validation, the questionnaire was consolidated and data were collected by a team of six people, supported by local staff from Civil Society Organizations and Universities, during the months of July and August 2010. This final version of the questionnaire, in Spanish, contained 80 questions, because it analyzed the agricultural practices in great detail. Over two weeks, each surveyor, accompanied by at least one local assistant, interviewed around 20 people. In several cases, it was necessary to translate the questions, or some of them, into the local language. A total number of 120 interviews were carried out in six communities during July and August 2010. During survey preparation and data collection, the research has faced two challenges: delays in obtaining MAGA and ENCOVI databases, and heavy rains affecting major roads and limiting access to rural communities.

Data entry and digital codification of results was carried out between September and October 2010. Data were analyzed first to obtain descriptive statistics. Continuous variables are presented as mean values and standard deviations, categorical ones as numbers and percentages. The analyses were performed with version 9.1 of the SAS statistical package.

Two Latent Class Analyses were then implemented [14,15] to define homogeneous

Latent Classes (or clusters) of people according to some variables in the data set. The analyses were performed with Latent GOLD v4.5 [16] and both categorical and continuous variables were allowed. The estimated parameters of the model were used to classify the respondents into the appropriate clusters and the profiles of the variables in each latent class for describing the classification.

Out of the 28 variables used for this research, only two (age and available land) are continuous, while the other 26 are categorical:

Age	Expressed in number of years, with 0 for no answer.
Sup	Expressed in the local measure querdas (400 m2) then converted into hectares.
Edu	Access to education, 1: yes, 2: no, 3: no answer.
Acserv	Access to basic services, 0: no answer, 1: no, 2: water and electricity, 3: 2+latrine, 4: 3+sewarage.
Foodcon	Food consumption, 0: no answer, 1: buy all, 2: buy most, 3: 50-50, 4: produce most, 5: produce all food
Fert	Soil fertility, 0: no answer, 1: fertile, 2: partially fertile.
Pract	Practices, 0: none, 1: hedgerows, 2: windbreaks, 3: ditches, 4: other, 5: no answer.
Rotat	Rotation, 1: yes, 2: no, 3: no answer.
Sowplan	Sowing plans, 1: yes, 2: no, 3: no answer.
Stub	Crop stubbies, 0: no answer, 1: burn, 2: leave in the ground, 3: compost.
Buyer	Buyer of output, 0: no answer, 1: Firm A, 2: Firm B, 3: Firm C, 4: Firm D, 5: Firm E, 6: others.
Cert	Certification, 0: no answer, 1: yes, 2: no.
Cred	Access to credit, 0: no answer, 1: yes, 2: no.
Tech	Access to advisors, 1: yes, 2: no, 3: no answer.
Techreas	Reasons for advice, 0: no answer, 1: buyers provide, 2: increase knowledge, 3: to protect environment, 4: to get better products, 5: other.
Techmod	Quality of advice, 0: no answer, 1: not good ….. 5: excellent.
Techapp	Implementation of advice, 0: no answer, 1: yes, 2: no.
Capbuil	Training on faming systems, 0: no answer, 1: yes, 2: no.
Accinf	Access to information on other crops, 0: no answer, 1: yes, 2: no.
CCroute	Impact of climate change on routes, 0: not at all, 1: little… 5: very much
CCtransp	Impact of climate change on transport of products: as above.
CCnatres	Impact of climate change on natural resources: as above.
CCmanag	Impact of climate change on management of crops: as above.
CCprod	Impact of climate change on annual production of crops: as above.
CCqual	Impact of climate change on quality of products: as above.
CCfeed	Impact of climate change on nutrition of family: as above.
CCprice	Impact of climate change on prices of crops: as above.
CCearn	Impact of climate change on annual income: as above.

3. RESULTS AND DISCUSSION

The average age of farmers is 36.7 years, with a minimum of 17 years and a maximum of 65, with most farmers around the mid-thirties (Standard Deviation 11.7). In terms of land availability, the average landholding is extremely small, around a quarter of an hectare (0.27 ha), with a minimum of 0.04 ha and a maximum of 1.6 hectares.

A large proportion of farmers (85.83%) have access to education, and slightly over two thirds (67.50%) have access to water and electricity, but their sanitation systems are mainly comprised of latrines. In terms of food consumption, over a third of farmers (39.17%) produce only between one and 20 percent of what they consume, while 24.17 percent produce half of what they consume. Only 2.5 percent produces all the food. Over half of the farmers (58.33%) consider their soil fertile and half of them (51.67%) do not implement any soil protection practice. Among the half protecting their soil, the most frequent practice is ditches (21,67%). In terms of agricultural practices, a large majority implements crop rotation (88.33%) and sowing plans (87.29%), while crop stubbles are left to decompose in the field by two thirds of farmers (66.67%). Burning residues is a fairly common practice for a quarter of farmers (27.5%). Over half of the respondents sell their products to the same processing firm (58.33%).

A relevant share (69.17%) sell their products without any certification. In terms of services, almost two thirds of farmers (63.33%) state they have access to credit, and over half (55.83%) have access to technical advice. The questions on rationale for receiving services and quality of services has a low rate of responses (in one case 50.83% and in the other 43.33% did not answer). Among the respondents, the most frequent answer (27.5%) is to increase their knowledge, followed by 11.67 percent affirming that they receive advice because the purchasing firms provide it. Over the 56.6 percent who answer about the quality of advice, half of the farmers consider it either regular (19.17%) or good (30.83%), and five percent excellent. Slightly over half of farmers (55%) have applied what learnt from advisors and 49.17 percent of them have received capacity building. Almost fifty-six percent of respondents do not receive information on other crops suitable to the climate conditions in their region.

The group of seven questions about climate change highlights that almost seventy percent of respondents confirm that the routes to their communities are affected by climate change (32% affected, 30.83% quite a lot affected, 14.17% very affected). Consequently, almost half the farmers (49.17%) affirm that climate change is affecting the transportation of their products, but there is a wide distribution around this answer. When asked if the climate change is affecting the conservation of natural resources, 44.17 percent respond positively and 21.67% that is more or less affecting. About the management of their production, only five percent do not perceive any problem, whereas the remaining ninety five percent demonstrates a normal distribution around the most frequent value (38.33%). Eighty percent of farmers report that climate change is not impacting at all the nutrition of their families (26.67%) or that it is only affecting partially (53.33%). The perception increases on annual production, as 38.33 percent consider it is affected and 35 percent highly affected. In terms of relation between climate change and the sale price of their products, over seventy percent consider it affecting with one stating that it is highly affecting (23.33% quite a lot, 10.83% very much so).

The Latent Class Analysis has been used to define homogeneous groups including variables of mixed scale types (both continuous and categorical variables) in the same analysis. Two different LCAs based on landholding as a covariate are presented: the first one defining two clusters along Human capital, and the second defining three clusters along Climate change perceptions.

The first multilevel LCA model with the best fit to the data estimates 6 latent classes of observed variables and 2 clusters of smallholders defined along those classes (Table 1). The two clusters are significantly different, with a p-value of 2.70 E-05, proving that along latent variables, the respondents are not uniform, and provide the basis for further insight. This analysis has highlighted two groups: a) the Small Unskilled (SU) cluster fits 77.18% of the smallholders interested by the survey, while b) the Medium Skilled (MS) clusters fits 22.82% of respondents.

The Small Unskilled (SU) cluster has an average land size of 0.22 hectares. Almost a third (59.81%) does not implement any soil protection practice, providing indications on low physical (land) and natural capitals and potential vulnerability to climate, weather related shocks and mid-term changes. This cluster is characterized by a low human capital: 64.16 percent of farmers have not received capacity building, 57.9 percent have not applied what learnt with technical assistance, and almost eighty percent (79.84%) sell their products without any certification. The majority of the farmers in this group (83.63%) however develop sowing plans, showing some agronomical capacity.

The Medium Skilled (MS) group manages 0.46 hectares, and most of the farmers (74.75%) implement soil protection practices. The consistent distribution across observed variables on technical advice, capacity building and certification indicates a fairly higher human capital. Almost two thirds (65.38%) sell certified products, and almost all of them have received capacity building (90.46%), have applied what learnt through advisors (95.32%) and are developing sowing plans (99.76%).

The comparison between the two groups reveals that, within the limits of extremely small land size, the Medium Skilled cluster has a land resource that is twice larger than the one managed by the Small Unskilled group (0.46 hectares versus 0.22). The Medium Skilled cluster also shows an importantly higher percentage of farmers who have increased their skills. The comparison

Table 1. Latent class analysis 1

	Name of cluster	Small unskilled	Medium skilled
	Cluster size	77.18%	22.82%
	Intercept	1.1347	-1.1347
Variables	**Modalities**	**%**	**%**
	None	59.81	24.13
	Hedgerows	7.53	19.04
Pract	Wind breaks	3.88	5.83
	Ditches	16.43	40.81
	Others	5.79	10.11
	No answer	6.56	0.08
	No answer	1.09	0.01
Sowplan	Yes	83.63	99.67
	No	15.28	0.32
	No answer	6.55	0.11
Cert	Yes	13.61	65.38
	No	79.84	34.51
	No answer	57.91	0.98
Techapp	Yes	42.09	95.32
	No	0.00	3.70
Capbuil	Yes	35.84	90.46
	No	64.16	9.54
Sup (mean))	Hectares	0.22	0.46

p-value 2.70E-05

highlights that smallholders with a relatively higher asset base, in terms of physical capital (land), also show higher rates of variables proxies to human capital (capacity building, innovation adoption) and potentially natural capital, derived from soil protection practices. Also the basic agronomical capacity (developing sowing plans) is higher for the Medium Skilled cluster.

The second multilevel Latent Class Analysis model with the best fit to the data estimates 7 latent classes of observed variables and land as a covariant along those latent classes defining three clusters. The three clusters (Tables 2 and 3) are significantly different, with a p-value of 5.10 E-10.

Most of the respondents (68.50%) are found in the Medium Resilient Aware (MRA) cluster; this group has an average farm size of 0.28 hectares. About the perceptions on how climate change is affecting the different dimensions of their communities and production system, over 60 percent (mean 3.19) affirm that climate change is affecting their routes of access. The perception on natural resources and management of production system is similar, with a mean value of 2.73 for natural resources and 2.90 for management of the production system, and in both cases the most frequent modality is 3 (yes affecting) with 47.90 percent on natural resources and 41.24 percent on the management of the production system. This group perceives that the feeding of their family is not yet affected by climate change, with a mean value of 1.05 and over half of farmers (54.97%) stating that climate change is affecting the feeding of their family just a little. However, half of the MRA cluster says that climate change is affecting their annual output, the prices of their products and their annual earnings, while 20 percent of the group consider that climate change is importantly affecting (respectively with means of 2.90, 2.60 and 2.81).

The Medium Adaptive Aware (MAA) cluster includes 21.74 percent of farmers and is characterized by an average land size of 0.26 hectares. The respondents of this group feel that climate change is very much affecting their routes of access (mean value of 3.64), show a mean value perception of the impact on the natural resources of 2.67, while perceive more important impacts of climate change on the management of their production system (mean value 3.40). However, around 70 percent of this group do not think that climate change is affecting the feeding of their families (52.74% respond little, 18.84% not at all), but over 90 percent consider that climate change is affecting the annual production (mean value 4.43) of their crops quite a lot (40.36%) or very much (51.55%). Similar mean values and distributions have been found for the other variables measuring how much climate change is affecting prices and earnings.

Table 2. Latent class analysis 2 – part 1

	Name of cluster	Medium resilient aware	Medium adaptive aware	Small vulnerable unaware
	Cluster size	68.50%	21.74%	9.76%
	Intercept	1.032	-0.1154	-0.9166
Variables	Modalities	%	%	%
	0 Not at all	0.96	0.27	1.19
	1 Little	7.53	3.03	8.70
CCrout	2 More or less	16.35	9.56	17.65
	3 Yes	33.54	28.58	38.89
	4 Quite a lot	29.45	36.56	27.82
	5 Very much	12.17	22.00	10.75
	Mean	3.19	3.64	3.11
	0 Not at all	4.13	4.82	45.67
	1 Little	7.48	8.24	23.06
CCnatres	2 More or less	21.77	22.66	18.72
	3 Yes	47.90	47.09	11.48
	4 Quite a lot	14.92	13.86	1.00
	5 Very much	3.80	3.33	0.07
	Mean	2.73	2.67	0.99
	0 Not at all	2.92	0.65	29.26
	1 Little	6.03	2.16	21.23
CCmngsys	2 More or less	22.37	12.89	27.78
	3 Yes	41.24	38.27	18.05
	4 Quite a lot	21.95	32.81	3.38
	5 Very much	5.49	13.22	0.30
	Mean	2.90	3.40	1.46

p-value 5.10E-10

Table 3. Latent class analysis 2 – part 2

Variables	Modalities	%	%	%
	0 Not at all	25.39	18.84	53.07
	1 Little	54.97	52.74	43.19
CCfeed	2 More or less	8.47	10.51	2.50
	3 Yes	11.17	17.91	1.24
	Mean	1.05	1.28	0.52
	0 Not at all	2.50	0.00	76.39
	1 Little	4.08	0.00	14.05
CCprod	2 More or less	18.37	0.20	7.13
	3 Yes	53.13	7.89	2.33
	4 Quite a lot	20.02	40.36	0.10
	5 Very much	1.88	51.55	0.00
	Mean	2.90	4.43	0.36
	0 Not at all	13.91	0.00	39.02
	1 Little	3.90	0.00	6.67
CCprice	2 More or less	11.56	0.15	12.43
	3 Yes	50.80	8.76	33.81
	4 Quite a lot	18.53	45.52	7.64
	5 Very much	1.30	45.57	0.33
	Mean	2.60	4.37	1.65
	0 Not at all	2.05	0.00	53.91
	1 Little	6.03	0.01	25.99
CCearn	2 More or less	18.68	0.37	13.22
	3 Yes	56.87	13.34	6.60
	4 Quite a lot	14.95	40.93	0.28
	5 Very much	1.42	45.35	0.00
	Mean	2.81	4.31	0.73

The Small Vulnerable Unaware (SVU) cluster fits only 9.76 percent of farmers, with average size 0.17 ha and highlights low mean values for all climate change variables. The only dimension that this group declares being touched by climate change is the access to routes, with over 60 percent aware of the problem and scoring a mean value above three (3.11). The perception of how much climate change affects the management of the production system and the prices of their product have a mean value around 1.5 (1.46 for the production system and 1.65 for the sale price) even though with very different distributions. Regarding management, about 70 percent of responses have concentrated on low scores, while on prices one third respondents reveal that their prices have been affected by climate change, versus 39 percent responding that climate change does not affect at all the prices. This cluster has mean values under the unit for all other variables, highlighting that they do not feel that climate change is affecting the nutrition of the family (mean 0.52), the production of crops (mean 0.36), the annual earnings (mean 0.73) or the natural resources (mean 0.99). The distribution of responses from this cluster around climate change implies that the Small Vulnerable Unaware are either less affected because of the mix of activities defining their livelihoods, or that they perceive climate change differently from the other groups because of capacities and behaviors. It is likely to hypothesize that the members of SVU might be less able to perceive tangible effects and therefore be more reluctant to implement adaptive behaviors, increasing their vulnerability to future shocks and climate change.

4. CONCLUSION

This study provides qualitative and quantitative evidence on the correlation between landholding size, human capital in farming communities and their perspective resilience in the Guatemala Highlands. Similar studies and indicators have been carried out in other situations, with analogous results [17]. Against their apparent homogeneity, these communities are composed by clusters, sub-groups whose components feel with different intensity the challenges posed by climate change. The increasing incidence of climate change, both in terms of frequency of extreme weather events, and in precipitation and temperature patterns, is generating more and more unpredictability, increasing the poverty and malnutrition in mostly subsistence agriculture. The entire agriculture of Latin America will experience the negative impacts of climate change [18]. This risk is even higher for those smallholders who have a really thin asset base, coupled with lack of knowledge, skills and technologies to mitigate risks and to adapt to changing conditions. When these very small producers try to diversify their production and their market outlets, through the involvement in distant markets – and even export oriented value-chains, their exposure to weather conditions could even increase, if this step towards modernization is not properly accompanied by measures implemented by public agencies and private companies, as suggested by [19], in both developed and developing economies.

From this survey conducted in the Guatemala Highlands, an important cluster of small and unskilled farmers has emerged, with extremely small landholding, related with a very low human capital. Similarly, when analyzing their vulnerability to climate change, a meaningful correlation has been seen, between land availability and lack of awareness of the risks related to climate change. All the different tools applied during this study suggest the existence of a minimum threshold of land, correlated to other factors, under which it might be potentially more difficult to deploy policies and strategies for improving smallholders' livelihoods.

The limited amount of assets available to smallholders implies the call for policies to enable the enjoyment of land rights and land accessibility, as affirmed by [20], the investment in hard infrastructure to reduce the transactional cost of accessing domestic and foreign markets, and the improvement of advisory services for strengthening the producers organizations, as indicated by [21].

Investments in agriculture and particularly in smallholder agriculture can generate public goods, such as poverty reduction and resilience to climate change but, to ensure that very small farmers can be enabled to survive and gain a decent income from their efforts, agricultural policies, legislative environment, quality and quantity of infrastructure, training and support should be provided by a mix of public policies and private sector interventions [22,23]. Any call for action on smallholder agriculture and climate change should aim at generating solutions throughout the value-chains, with the engagement of several actors, to invest in

adaptive solutions tackling infrastructures, technologies, capacities and knowledge.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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