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Sustainable Agricultural Intensification – A Perspective from Latin America and the Caribbean

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Abstract: Sustainable agriculture is broadly established in Latin America and the Caribbean (LAC), but the way that food is being produced and consumed requires rethinking. Sustainable agricultural intensification (SAI) is becoming an approach to address various complex challenges in agriculture. A total of 760 participants (57% LAC) from 101 countries registered for a 2-week e-consultation, which included 3 components with the aim of promoting the dialogue and partnerships on SAI in LAC. In the first component there was an exchange of ideas on its conceptual framework, while in the second component experiences and lessons learned from programs, practices, policies and solutions to address challenges in the region were shared, and the last component served to discuss how to increase regional cooperation through the identification of actors and actions. This paper provides a synthesis report of the e-forum and the main recommendations to consolidate a regional SAI network to exchange experiences and generate joint actions for greater synergies in agricultural research, and better policies, investments and institutions in LAC. Proposed research areas are: analyzing yield gaps, accurate mapping of farming structure of LAC agriculture, rehabilitating degraded lands, curbing deforestation, studying the nature of the interphases between sustainable agricultural and food systems, reducing food wastes, adapting to and mitigating climate change, strengthening cooperatives, building local organizations and linking farmers to markets, using information and communication

technology to access information and share knowledge on SAI, and defining indicators and metrics to monitor SAI undertakings and assist policy makers for enacting incentives through related policy.

Keywords: agro-ecology; eco-efficiency; Latin America and the Caribbean; resilience; sustainable agricultural intensification.

1. Introduction

In Latin America and the Caribbean (LAC) sustainable intensive agriculture is a broad and well-established approach, however, is not yet considered as a vision that requires a global rethinking on how food is produced and consumed. There are various options for intensifying agriculture. They differ in their biophysical, technological, socio-economic and ideological features, which may affect differently the land farming structures, e.g. conventional agricultural intensification through inputs use, water management, mechanization and genetic improvement (the Green Revolution approach) [1]; organic agriculture [2]; agro-ecology [3] and sustainable intensive agriculture (Florent Maraux, CIRAD, personal communication). Sustainable Agricultural Intensification (SAI) is becoming a world priority in the search for addressing the many complex challenges facing agriculture in the twenty-first century. There are various schools of thought regarding sustainable intensification of agriculture that rely on integrating the use of a wide range of technologies to manage pests, nutrients, soil and water [4]. SAI offers a pathway towards producing more food with less impact on the environment. In the past, intensification - increased production, yields or income per unit of land depended significantly on a great use of capital, labor, or inputs such as fertilizers or pesticide. Nowadays, intensification can take many forms according to climate and land, household resource endowment and socio-economic states, individual choice and market demands.

The Montpellier Panel [5] states that “SAI aims to have a smaller environmental footprint by minimizing the use of fertilizers and pesticides, generating lower emissions of such greenhouse gases as carbon dioxide, methane and nitrous oxide and, at the same time, contributing to the delivery and maintenance of a range of public goods, such as clean water, carbon sequestration, flood protection, groundwater recharge and landscape amenity value.” The prudent use of resources, efficiency in seeking returns and in reducing waste, resilience to future shocks and stresses, equity for inputs and outputs that are accessible and affordable by producers and consumers, a “no one size fits all” approach, and the existence of trade-off in time and space –i.e., all outcomes cannot be achieved at once or simultaneously everywhere– are among SAI principles. At the operational level SAI implies actions in three strategic intensification pillars: socio-economic, ecological and genetics. Socio-economic intensification refers to creating enabling environments, addressing markets, building social and human capital and creating sustainable livelihoods, while intercropping, integrated pest management, conservation farming and organic agriculture, *inter alia*, are included in ecological intensification. Genetic intensification should target increasing edible yields, enhancing nutrition, breeding host plant resistance to pathogens and pests, and building resilience to climate change, among others.

The CGIAR is a global partnership that unites organizations engaged in research for a food secure future. Its name comes from the acronym for the Consultative Group on International Agricultural Research. In 2008 the CGIAR underwent a major transformation, but to reflect this and yet retain its roots, it keeps CGIAR as its name. The CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources. It is carried out by 15 Centers, which are members of the CGIAR Consortium, in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector. The 15 Research Centers generate and disseminate knowledge, technologies, and policies for agricultural development through the CGIAR Research Programs. The CGIAR Fund provides reliable and predictable multi-year funding to enable research planning over the long term, resource allocation based on agreed priorities, and the timely and predictable disbursement of funds. The multi-donor trust fund finances research carried out by the Centers through the CGIAR Research Programs. In order to address potential gaps in SAI for LAC and taking into account the experience in this field developed by the CGIAR system, the CGIAR Consortium in coordination with key partners and with the sponsorship of Canada's International Development Research Centre (IDRC), proposed an action plan whose first component was a broad electronic consultation. The main purpose of this e-forum was to address key issues regarding the major elements of a sustainable development strategy and raise central questions for an open discussion among interested stakeholders.

2. Results and Discussion

A total of 760 participants from 101 countries (including 25 from LAC) registered for this e-consultation. About 57% has LAC as their main work pr action region, while other important regions were Africa (17%), Asia (12%) and Europe (4%). At least 5% of participants declared to have had a global work scope (Figure 1).

Most of the participants (24%) are working in academics, 18% in national research institutes and 11% in government (Table 1). About 19% of the participants were from the private sector civil society organizations such as NGOs and farmers' associations.

There were 212 contributions in the e-forum (excluding the e-moderator and the e-consultation team), with most postings in Component I (50%) and Component II (35%). The total views (up until the writing of this Synthesis Report) were 3.000. The Component I was the most read (35%), followed by partial summaries and reminders (28%). The active participation was therefore above expectations because within Internet consultations and fora, the 1% rule states that the number of people who create content on the Internet represents approximately 1% or less of the people actually viewing or following that content. For example, for every person who posts on a forum, generally about 99 other people are viewing that forum but not posting.

2.1. Component I - Conceptual Framework of SAI from the perspective of LAC

The following four questions guided the exchange of ideas in this first component: (1) What are SAI opportunities and pathways in LAC that are currently not exploited? (2) SAI in LAC can play a dual role through improving global food supplies and contributing to regional poverty alleviation, food security and addressing nutrition challenges. Are these roles conflicting? Under which conditions can

they be made reinforcing? (3) What are key food systems issues or constraints that should be integrated into SAI strategies? and (4) Given that family agriculture is one of the main segments of the region's agriculture, what is the policy and new business models that could serve to support its growth and consolidation within a SAI perspective?. Table 2 list some issues brought by the participants for a conceptual framework of SAI for LAC.

These were two further questions that SAI conceptual framework for LAC should address: Are modern cultivars along with agrochemical inputs such as fertilizers and pesticides, and the use of more water the best to increase production when pursuing SAI? and What will be the role of the seed industry for developing sustainable systems for smallholders?

2.2. Component II – Experiences and Lessons learned in SAI in LAC

This second component of this e-consultation was facilitated by exposing six case studies (available at <http://sai-lac.cgiar.org/case-studies>) that dealt with atlas of yield gap, improving sustainability of ranching in the Amazon through satellite monitoring and improved local governance, innovation to value native potato biodiversity in dynamic markets (the case of the “Papa Andina” in Perú), livestock-agriculture-forest integration in Brazil, sustainable modernization of traditional agriculture in Mexico (MasAgro), and integral analysis of production systems in Colombia towards adaptation to climate change. Participants also communicated their experiences on SAI or related cases. They included zero-till agriculture and direct seeding in Argentina, the sectorial plan for climate change mitigation and adaptation and for the consolidation of the low carbon agriculture (known as ABC Plan) in Brazil, or soil conservation policy in Uruguay, among others.

These other four questions guided the exchange of ideas on the second component: (1) What are the major issues emerging from existing SAI experiences in the region? (2) Given the discussions so far, what could be five new major focus areas for agricultural research on SAI technologies and pathways? (3) What could be summarized to be the major political, institutional, or technological obstacles to the successful implementation of SAI visions and strategies in LAC? And (4) Which is the most adequate mechanism to promote the exchange of new knowledge and SAI informed experiences among LAC countries facing similar SAI challenges/opportunities? Table 3 lists some topics brought by the selected cases or that emerged during the e-forum.

2.3. Component III – How to increase regional cooperation. CGIAR role

This e-consultation began in its 10th day with this component and asking two important overall questions to all participants: (a) How to increase regional cooperation through the identification of actors and actions? and (b) The role of CGIAR? The following four questions guided further the horizontal e-exchange of ideas in Component III, which aided shaping a regional SAI agenda with a potential for global spillovers: (1) What kind of human and institutional resources will be needed to develop and implement the identified SAI innovations, and by whom and how could they be developed? (2) Considering that public-private partnerships (PPP) are an efficient and cost effective mean to develop agriculture outcomes, which could be promising approaches to promote PPP solutions for SAI in the region? (3) What can be learned from SAI success stories in the region that may be further shared with other continents? Through which mechanisms and what could be the role of the

CGIAR in this process? (4) Which critical contributions could the CGIAR make for enhancing SAI in LAC? What kind of partnerships should be emphasized for greater impact? Table 4 includes some actions proposed by the participants needing CGIAR's follow up.

The answers given by the participants and their other comments during this component III of the e-forum are given in Table 5. They envisage and acknowledge the roles given to the CGIAR in this endeavor.

2.4. SAI approach for LAC: as synthesis from the e-forum

The Latin America and Caribbean region has an acceptable environmental performance, but its production potential needs to be set in the context of increasing pressures on the natural resources base, particularly with respect to forestry resources and to the risks confronting agricultural production. The agricultural intensification – increased production, yields or income per unit of land– has essentially relied on greater use of capital, labor, or inputs such as fertilizers or pesticides. The intensification can take various forms depending on climate and land, household resource endowment and socio-economic states, individual choice, agri-food processing and market demands. SAI offers, instead, a pathway towards producing more food with less impact on the environment in LAC, where family farming is a key segment of agriculture and coexists with rural and urban agri-business. A SAI approach for LAC should also take into account food loss, which according to FAO [6], amounts to 6% of world food loss in this region and to 15% of all available food every year in LAC. About 28% of this food loss occurs at the consumer level, while 28% at production, 17% during distribution and at the market place, 22% during handling and storage, and the remaining 6% when processing.

The exchange of ideas in the first four days of this electronic consultation clearly highlighted that SAI is a high priority because (a) agriculture today requires, without doubt, intensification that needs to be sustainable, and (b) the emerging knowledge for implementing SAI is just in its infancy, which calls for more research on SAI. It was argued that any SAI undertaking should involve, from the onset (i.e. planning), farmers, end-users, civil society organizations, and public and private sectors. Everyone participating in SAI needs to use the same vocabulary and jointly define the approach and methods, which should be culturally sensitive and cost-effective. Hence, stakeholders must be involved in priority setting and on defining the “road map” through a participatory bottom-up approach that will involve diverse actors along the impact pathways. Their participation should be conscious, committed and responsible. Local innovation systems will play a crucial role for implementing SAI. A challenge could be on the methodology to involve SAI stakeholders in participatory action research (PAR), which should be farmer-led to impact on smallholders' livelihoods.

It will be desirable to analyze actual and potential farm yields to determine yield gaps in each region and identify the most suitable sustainable intensification options. Defining clear goals and indicators for SAI will further allow its monitoring throughout impact pathways and assist on identifying suitable intensification options (ecological, genetic and socio-economic) to achieve targets, which may be disaggregated by sectors or sub-regions. In this regard, SAI must be assessed on technology criteria along with productive, economic, energy, social and ecological efficiencies, e.g. measuring the intensification factor in terms of process efficiency that accounts for relationships of resources and input versus output.

Most participants recognized “one size does not fit all” for implementing SAI because its approach depends on agro-ecological, socio-economical, institutional and policy factors, which vary according to the context, and on how to achieve food and nutrition security while reducing poverty and preserving agro-ecosystems. SAI must therefore consider *inter alia* indigenous knowledge and

resources (particularly biodiversity), ethnic and cultural richness and preferences, species and landscape diversity, and the very particular dichotomy between small and large agriculture in LAC that targets various end-users locally and globally. This also calls for linking farmers to markets and value chains.

The SAI framework should consider a strategic integration with the sustainable food systems framework, which offers the needed urban-rural linkages and through the important urbanization level in the region (currently higher than 75%), include the rapidly changing urban diets focus (and hence the double burden of under and over nutrition).

The sustainable intensification of agriculture should aim to enhance family and other farming contributing to food security. SAI should therefore seek improving rural livelihoods and contribute in such a way that smallholders stay in farming, although this will likely depend on the country's policy for agriculture and rural development. There are many success cases on family farming and small-scale entrepreneurship that need to be well documented because some of them may be replicated in other areas.

Revamping extension systems and training along with sustainable agriculture in both at the university and technical institute levels should be pro-actively pursued in LAC. Curricula will likely change for educating on SAI, which requires a philosophy, a holistic approach, and multidisciplinary skills involving many actors throughout the value chain in agri-food systems. This change of education and training at all levels will bring to a larger scale the SAI concept, which must be kept related to agri-food systems. The increasing awareness among key actors about the changes brought by SAI brings a new challenge: changing oneself.

Some participants indicated that agro-ecology should be regarded as the main technological pillar for food sovereignty. In their view peasants already adopted such an approach in LAC and elsewhere as noted in various publications available at <http://agroeco.org/publications/>. Other participants indicated that some farmers, especially those with few assets and in an unfavorable context (about 10 out of 15 million production units), chose diversification strategies of jobs and income, which calls for acknowledging the heterogeneous agro-ecosystems, farming and growers in LAC. In this regard, SAI may be a useful approach to focus the use of resources and maximize their impact at the local, regional and global levels particularly for the remaining 5 million production units, which account for 300 million hectares. The challenge will be how to assist low-productive farming to becoming sustainable, productive and profitable, particularly for poor smallholders.

It was noted that the scope for yield increase should be determined before embarking on SAI because yield differs from place to place and depends on various factors. Yield gap analysis assists by revealing the potential opportunity for intensifying agriculture [7]. Baseline data on yield may be the starting point for any undertaking aiming SAI, which should be regarded as an aspiration of what needs to be attained, rather than a "prescription" on how to do it. As noted elsewhere, SAI provides a framework for exploring what mix of approaches may work best based on the existing biophysical, social, cultural and economic context, with the goal of improving agricultural system more efficiently.

Some participants indicated that "producing more with less" should not be just associated with increasing production per unit area but also by reducing input use, especially those that are becoming scarce (e.g. water) or may damage the environment because of misuse (e.g. fertilizers or pesticides). This definition is important from both environmental and economic viewpoints, to understand yield gaps and to identify promising SAI interventions. A whole-system perspective must also consider productivity for the entire cropping systems and rotations, and for integrated crop-livestock-tree systems to understand yield gaps and to identify the most promising options to narrow them.

It became clear during this exchange of ideas that SAI practices vary because they should relate to

the specific characteristics of the site and context. Hence, the success when taking the SAI approach will depend significantly on the ability of farmers to access and adapt cultivation techniques and management of complex resources to the specific attributes of their farms. Likewise, farmers – particularly smallholders – must access appropriate technology options and other research products, and will benefit from knowledge sharing on how to sustainably intensify agriculture, which could be facilitated by information and communication technology, e.g. mobile phones.

High standards and certification systems on agricultural produce call for institutional innovations that enable smallholder and family farming to achieve the necessary scale. Strengthening farmers' associations or any form of integration may allow them to operate efficiently, sustainably and achieve the economies of scale.

Table 1. Type of participants.

Type of Institutions	Quantity	%
Academic Institutions	185	24.3%
National research Institutions	138	18.2%
Government	87	11.4%
International Agricultural Research Centers	65	8.6%
Non-governmental organizations	64	8.4%
Private Companies	63	8.3%
Regional organizations	34	4.5%
Farmers Organizations	23	3.0%
International organizations	22	2.9%
Advisory Services	21	2.8%
Development organizations	20	2.6%
Foundations	13	1.7%
Financing institutions	3	0.4%
Others	22	2.9%
Total	760	100%

Table 2. Some issues for a sustainable agricultural intensification (SAI) conceptual framework.

LAC, particularly its Southern Cone, is a global food supplier, however, poverty and food security remain relevant challenges among and within countries
There will be a challenge for balancing the process (HOW) and content (WHAT) when formulating a SAI strategy and for discussing its core elements
Soil health is essential for sustainable productivity intensification
Rise agricultural productivity through low-cost and practices and technology, which depend more on knowledge than on capital, well-suited to family farming
Research-in-development should consider learning processes that engage farmers in learning-by-doing and discovering, e.g. farmer field schools that are very promising for knowledge-intensive innovations
SAI approach should include linking farmers to value chains by investing in their education and empowerment
Policies should help small farmers to access land, credit and markets (avoiding many intermediaries)
There should be incentives for farmers who adopt and implement SAI because of increasing production or reducing yield gaps while conserving the environment

Table 3. Some emerging topics from selected case studies and participants.

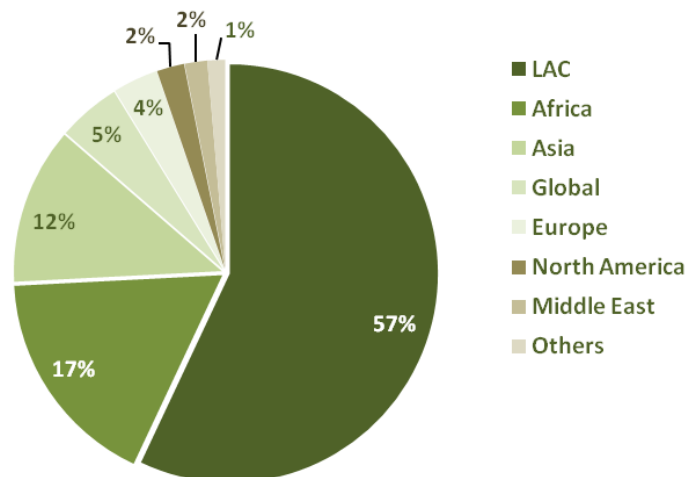
The importance for country's policy to give priority to food security and agri-food processing industry that minimizes food wastes, which call for postharvest technology to have a high profile in LAC value chains
LAC should consider contributing to sustainable development goals (SDGs) related to food and nutrition security through a SAI approach
Actual and potential yield have to be analyzed to know the yield gap to assist finding a strategy suitable for each region under the concept of 'more crop per drop and piece of land'. This research needs to define crops and target regions and determining whether available or new tools are to be used for such a research undertaking whose outputs should guide investments by policy makers, agri-business, civil society and farmers based on an understanding of both yield gaps and the most constraining inputs
Local knowledge, food preferences and ecology of the region should be taken into consideration while preparing for the SAI in LAC
Robust tools and metrics for assessing performance and resource use efficiency as well as sustainability will facilitate comparative research to fully unlock the potential and the limitations of the SAI approach
A much more systematic research to be pursued on pathways to integrate cropping, ranching and agroforestry
Appropriate and proven technology options are essential for South-South learning and exchanges
Be proactive on informing LAC policy makers about the impacts of climate change on agriculture, food and nutrition security to influence investments. Modeling, scenario-analysis and science related to climate change can assist in this endeavor
Further research regarding greenhouse gas (GHG) emissions and their implications of intensification will be very important. For example, intensification of agriculture may impact positively by reducing deforestation, but livestock intensification will likely increase GHG emissions from enteric sources. Hence, more quantitative data on both will assist understanding the balance between them, and the related climate change implications
The horizontal integration that benefits farmers' associations requires institutional strengthening to ensure that rules are clear and efficient when gathering them

Table 4. Areas proposed by participants that CGIAR should follow up.

Alliances of strategic partners working in the SAI are essential. The CGIAR should work together with other international and sector groups sharing interest on applying SAI
LAC cooperation will be further enhanced by the CGIAR through regional SAI programs and projects as well as by organizing annual meetings with research-for-development partners stakeholders (including policy makers). These meetings will also allow exchanges on advances, hurdles and successes while implementing SAI
Training, exchanges and study trips could be facilitated by the CGIAR to enhance regional cooperation
The CGIAR should give priority to research on farmer learning processes for transfer of knowledge-intensive innovations
Translating the SAI concept into practice requires a better understanding and measuring sustainability quantitatively, as well as recognizing that sustainability will be highly context-specific. Hence developing both metrics to measure and quantify the multiple stands of sustainability with appropriate and robust data sets is both a need and an opportunity. The CGIAR Research Programs (CRPs) should provide strong intellectual and practical leadership in this important area
'Big data' programs will require extensive collaboration and is an area of growing interest to the private sector. Exploring collaborative opportunities around 'big data' to develop faster and deeper insights into SAI could be an interesting topic for a public-private partnership

Table 5. Recommendations: regional cooperation and the role of CGIAR

<i>The overall role of the CGIAR</i>				
<i>Main Goal</i>	To become a <i>facilitator</i> of a SAI network in LAC			
<i>Undertakings</i>	After collecting information from various sources share successful SAI with regional stakeholders through an online network	Close SAI knowledge gaps by training, exchanges and study trips that will also enhance regional cooperation and influence policy	Develop learning and other alliances of strategic SAI partners who are working in the same area to ensure measureable success	Working with development banks and other investors, help national partners to formulate projects for scaling up promising SAI innovations
<i>Main Tasks</i>	<i>Advocate</i>	<i>Bridge</i>	<i>Broker</i>	<i>Catalyst</i>
<i>Specific Activities</i>	Compile plans, projects, proposals, manuals, handouts, brochures and videos on SAI and put them into an online database Influence decision makers to adjust agricultural policy towards a SAI approach	Train on SAI at all levels: farmers, university students, trainers, researchers, extensionists and policy-makers Organize SAI meetings for exchanges of success and issues related to its adoption in LAC	Assist on building multidisciplinary teams across organizations engaged in SAI Forge long-term public-private partnerships along the various SAI issues needing research-for-development or for scaling up and out	Research on farmer learning processes to transfer of knowledge-intensive innovations Develop metrics to measure and quantify sustainability with sound and robust datasets
<i>Some potential priority research subject areas for SAI in LAC through CGIAR-facilitated partnerships</i>	<ul style="list-style-type: none"> • Yield gap analysis • Accurate mapping of the farming structure of LAC agriculture • Degraded land rehabilitation • Curbing deforestation • Analysis of the interphases between agricultural and sustainable food systems • Reducing food wastes • Adapting to, and mitigating climate change • Strengthening cooperatives, building local organizations and linking farmers to markets • Using information and communication technology to access information and share knowledge on how to sustainably intensify agriculture • Defining indicators and metrics to monitor SAI undertakings and assist policy makers for enacting incentives through related policy 			

Figure 1. Distribution of participants according to continent or work scope.

3. Experimental Section

This electronic consultation had three components with the aim of promoting the dialogue and partnerships on SAI in LAC, namely, Component I – Promote the exchange of ideas on a conceptual Framework of SAI from the perspective of LAC; Component II – Share experiences and lessons learned from programs, practices, policies and solutions to address SAI challenges in LAC; and Component III – Recommendations on how to increase regional cooperation through the identification of actors and actions, and the role for the CGIAR in this endeavour.

Participants were encouraged to register. By signing up, they ensured to get partial summaries and this synthesis report through e-mail. Various documents (both in English and Spanish) were written as reference materials ahead of the e-consultation. Documents published by other institutions were available in the language they were published through the website setup for the e-forum. This website also provided details to all who participated in the e-consultation. Contributions were made both in English and Spanish. Participants were assumed to make contributions on their own behalf and not on behalf of their employers (unless indicated otherwise). There was no limit on the number of interventions per participant. There were e-Q&As through the e-forum with some members of a Science Advisory Panel and with those who kindly wrote SAI piece-thinks or provided details of relevant SAI in or to LAC. Partial summary reports were given for components I and II during the electronic consultation. All documents and postings are at <http://sai-lac.cgiar.org/>.

4. Conclusions

We had, even when we agree to disagree, a dynamic, constructive and valuable exchange of ideas regarding the conceptual framework of SAI from the perspective of LAC during the first week of this e-consultation. At the end of the first and beginning of the second week several participants brought to our attention examples of SAI in the continent, which may show location-specificity, particularly due to the very heterogeneous LAC agriculture. In the last half-week the participants provided very thoughtful and useful answers to the questions guiding the last component of this e-forum. Their feedback will help the CGIAR and partners to shape a SAI agenda through a continuous consultative process, which will include farmers, civil society organizations, national agricultural research systems, academia, public and private sectors.

As a follow up of this e-consultation, it is expected to consolidate a regional network to exchange experiences and generate joint actions for greater synergies in agricultural research, and better policies, investments and institutions in LAC. This horizontal exchange of ideas will also allow confirming a regional SAI agenda with global reach.

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Conflict of Interest

The authors declare no conflict of interest.

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