Approaching agricultural supply chain performance and strategic sustainable development

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Abstract: In Costa Rica, a large proportion of small farmers harvest roots and tubers in some of the poorest regions of the country. Addressing this, supply chains sustainability and performance intends to analyse intrinsic characteristics and the potential socio-economic benefits and development routes, including: food security, value added, economic performance, productivity and sustainability. This research proposed a tool for the analysis of supply chain performance; composed by a Delphi study creating indicators and a gap analysis between current performance and best-possible performance. The analysis used information from: in depth interviews with stakeholders and questionnaires with farmers (128), private companies (9) and consumers (515). Finally, a workshop with all parties involved validates our tool and outcomes. Results indicate potential for better loss and waste management, (especially cassava), and a strong legislative system that sometimes limits bio-economic innovations along the supply chain, coupled with governance mechanisms that tackle development and supply chain performance.

Keywords: supply chain management; development; sustainability; roots and tubers.

JEL codes: O13, Q13, Q56.

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1 Introduction

Roots and tubers (R&T) grow in climate conditions in which other products can fail, for example, cassava can be harvested in conditions near to drought; additionally it has higher starch content than most grains and potato (IFPRI, 2000). Therefore, these products may play an important role when addressing food security and economic development of productive regions. According to Petsakos et al. (2019), an increase of 16.4% production is expected for 2050, mainly in Africa and developing countries. Contrary with these estimations, production of cereals is expected to decrease worldwide, which entails shifting consumption patterns. On the other hand, due to Covid-19's pandemic the World's gross domestic product (GDP) is expected to decrease between 4% and 1.5%. These conditions and forecasts indicate the importance R&T may have for the rural poor.

The pandemic has also affected the Costa Rican agricultural sector, and because of decreases in production, availability, distribution and unemployment, hundreds of people related to the R&T supply chain (SC) have been affected. The main R&T production regions in the country have a long history of lesser development when compared to the rest of the country; these are also some of the most affected by the pandemic; especially because they are linked to tourism and to agricultural exports. Therefore, it is imminent to address development strategies that allow economic reactivation; this is especially for vulnerable populations such as those in which R&T are produced.

Although there are many ways to measure the performance of the SC, the theoretical and methodological contributions tend to concentrate their efforts mainly at an industrial level (Ferreira and Otley, 2009). Our work seeks to achieve a more holistic analysis, considering factors not only specific to the R&T SC (which has a greater need for resilience as it is subject to the unpredictability of nature) but also on how local development is influenced by it in a framework for developing country value chain analysis as proposed by Trienekens (2011). Our analysis goes beyond the logistical-productive performance and considers development indicators, institutional and legal requirements and incentives.

The main drivers to this research rely on two aspects: the reduction in economic growth because of the pandemic and the social impact of this disruptive event in some of the most vulnerable regions and farmers. We compare the ideal 'state' of performance of the SC and its current performance; with the purpose of determining those variables with greater urgency of improvement for SC competitiveness and regional development.

Within the R&T sector, the largest economic setback is observed in exports, follow by national consumption and finally in governmental purchases (for hospitals, prisons and education). As well as in the rest of the world, education was put on hold and reorganised through virtual education during 2020. But to tackle food insecurity and hunger as well as propelling development, kids enrolled in public education were provided with at least two meals a day, despite virtual environments.

This research analyses the current SC performance; our goal is to address SC management, its performance and opportunities of sustainable development for agriculture and other related industries. This is also an opportunity to take advantage of the situation and incorporate innovation for SC development. According to several SC and sustainable supply chain management (SSCM) definitions and performance measures, we developed a tool for addressing SC performance within the Costa Rican R&T SC. This performance measurement intends not only to address the SC's characteristics but also the potential socioeconomic benefits and development routes for better performance, considering mayor gaps between current performance and its potential.

2 Theoretical framework

Resource scarcity and current sustainable demands have forced economic systems to transform into new sustainable business models, altering SCs (Rashid et al., 2013). Progressively, transactions have become more complex, multi-echelon and geographically extended; which forces firms to aim for sustainable development rather than just to compete for market share (Saberi et al., 2019) and inputs.

The adoption of green models and sustainable structures has evolved as well as the diverse definitions of SCM. Cooper and Ellram (1993) defines it as "an integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user". From this point of view, authors addressed the importance of linkage and collaborative work among stakeholders to develop competitiveness. The latter can be achieved through vertical integration or 'best performers' in a competitive market.

Mentzer et al. (2001), Seuring and Müller (2008a), Gold et al. (2010) and Jarzębowski and Bezat-Jarzębowska (2016) also highlighted the importance of collaborative improvement towards competitive advantage and efficiency to become part of a bigger SC management system, where the information, risks and rewards are shared, and commitments are based on long-term relationships. For example, Mentzer et al. (2001) determined lower costs, competitive advantage or higher customer satisfaction are key performance indicators for SCM.

When shifting from traditional SCM into SSCM, the concept introduces environmental and social criteria as well as creating better relationships among stakeholders. Specifically, Carter and Rogers (2008) presented a definition of SSCM based on the four facets of sustainability (risk management, transparency, strategy, culture) On the same note, Seuring and Müller (2008b) 'conceptual framework addressed two ways of SSCM adoption:

a triggers for SSCM; which is basically understood as a focal company suffering pressures and incentives of consumers and governmental control (e.g., customer or legal demands, environmental and social pressure groups, reputation loss, etc.)

b supplier management for risks and performance, that emphasises on identifying all internal features that act as barriers, and enablers of sustainability goals.

The latter requires constant training of employees and suppliers (Seuring and Müller, 2008b).

The analysis of Seuring and Müller (2008b) on how companies adopt SSCM measures is similar to that form (Cooper and Ellram, 1993). Both establish that competitiveness or success in management is attained from a collaborative strategy that can either be achieved by a 'upper vertical' approach (top-down) or from a 'customer pressure' (bottom-up) in which a focal company passes its sustainable requirements upstream in the SC. Regardless of the dynamics used by the SC to emerge into sustainable and competitive practices, most authors have used indicators to measure SC performance.

When shifting from theoretical definitions to empirical SC performance measurement, several authors have stated their own measurement tools and approaches. Since there is no universal definition of either SCM or SSC, performance measurements also vary. Aramyan (2007) addresses SC performance in the agricultural sector considering indicators derived from several variables. These are: customer responsiveness (shipping errors, lead time, and customer complaints), efficiency (cost, profit, return on investment, inventory), flexibility (customer satisfaction, delivery flexibility, back orders, lost sales).

Gunasekaran et al. (2004) analysed several performance evaluation methods. Results indicate that planning mechanisms (order entry method, order lead time, customer order path), strategical sourcing (capacity utilisation or effectiveness of scheduling techniques) and consumer satisfaction (delivery performance, distribution costs, customer service satisfaction) are among the most solid indicators to address performance.

Wittstruck and Teuteberg (2012) – although in the electrics and electronics industry – addressed SSCM success in view of the increasing cost pressure and demands on SC. Their results indicate that companies that communicate their sustainable activities find cooperative partners more easily, therefore 'signalling can be a critical factor for successful cooperation'. Constant exchange of information between stakeholders, as well as 'information provision' and 'strategy commitment' are decisive factors for successful of sustainable chains.

Chopra et al. (2017) investigated the role and relationship of the rice stakeholders in India to identify and comprehend relevant performance indicators. Their results are divided in four categories: efficiency (costs, production/distribution, profits, return on investment and inventory), flexibility (customer satisfaction, volume and delivery flexibility), responsiveness (fill rate, product delay, lead time, customer response time and complaints) and food quality (sensory properties and shelf life, product safety and health, product reliability, production system characteristics and marketing).

Font et al. (2008) defined SSCM "…it as an extension to the traditional concept of SCM by adding environmental and social/ethical aspects". These social and ethical aspects are a common topic on performance and they have proven to increase SC performance, for example, Jie et al. (2013) determined that trust among stakeholders and the quality of information shared are the main drivers towards generating competitive advantage.

Since several definitions have been placed on sustainability and SCM, Ahi and Searcy (2013) made an extensive comparison of definitions between SSCM and a green supply chain management (GSCM), finding 22 different understandings for GSCM and twelve definitions for SSCM. These authors proposed a series of key characteristics in two different levels to evaluate every definition, starting with elements related to business sustainability (economic, environmental and social focus, resilience focus, stakeholders among others), and flows, coordination, relationships, performance. Results indicate that some approaches of GSCM emphasised on environmental characteristics, rather than other components, however, there is a thin line between both definitions (Ahi and Searcy, 2013).

3 Methods

Addressing SSCM can be challenging since we can address performance from different viewpoints and SC definitions. Nevertheless, measurements are composed of indicators that englobe aspects that define performance (Chardine-Baumann and Botta-Genoulaz, 2014; Kurien and Qureshi, 2011). In this case, since our goal was to merge sustainable development indicators with agricultural SC characteristics, traditional indicators are used, as well as new ones focused specifically on regional development. This research is based on development, rather than solely on SSCM; therefore indicators consist of regional socioeconomic development and SSCM, because of the R&T chain potential for development and food security of the rural poor has been heavily documented within Costa Rica (Madrigal Quirós et al., 2007; Contreras et al., 2007).

The triple bottom line proposed by Elkington (1999) which is heavily used when addressing SSCM performance, considers environmental, social and economic indicators. These are transversally included in categories used in the analysis, therefore variables regarding environmental topics (such as waste and legislation), economic (such as profitability, technology, costs) and social (stakeholders' capabilities and development indicators) topics are distributed long the variables and indicators.

Although, according to Hossan Chowdhury and Quaddus (2021), there is a "genuine lack of a theoretically justified and empirically validated integrative scale for supply chain sustainability" (SCS), we developed a scale that considers development variables (Territory indicators and variables in Table 1), Stakeholders' capabilities within the SC (Table 2) as well as institution and regulatory framework that can either support or undermine a global value chain (Tables 3 and 4) and market characteristics (Table 5), which are aligned with traditional SC performance measures. Trienekens (2011) considers production of (additional) value adds, organisational arrangements and markets willingness to pay for value added as SC upgrading options which we included as: producers capabilities (Table 2), institutions and legislation (Table 3 and 4) and consumer behaviour (Table 5).

Territory indicators and variables include only development indicators from the territory. These variables are used to address the development approach intended. Topics such as efficiency and responsiveness which Aramyan (2007), Wittstruck and Teuteberg (2012) and Chopra et al. (2017) considered mandatory when analysing performance, are included in SC indicators and variables, nonetheless it is measured from the stakeholders capabilities instead of the customers' evaluation.

'Inadequate government supports are identified as barriers to SSCM implementation' (Sajjad et al., 2015) therefore these were included from two indicators: institutional support and legal support (Tables 3 and 4). Mandatory compliance of international and regional laws as well as incentives promoted by national and international institutions provided to actors of the SC contributes to the creation of the SC governance mechanisms. In this regard, the global value chain analysis proposed by Gereffi et al. (2005) considers both as key mechanisms in addressing the possibilities of SC upgrading which is aligned with our development perspective.

Seuring and Müller (2008b) which had been one of the highly cited publications – market and stakeholders demands for sustainability (Beske, 2012). These variables in our research are included in Table 5 which address consumer behaviour, that include trust as mandatory for consumers to buy produce and for the SC to attain a competitive advantage (Jie et al., 2013). Exports and national consumption rates are considered because according to Wang et al. (2010) members of the SC require positive performance outcomes of a relationship in order to retain participation in collaborative activities (Wang et al., 2010).

Table 1 Territory indicators and variables

Indicator	*Variable*
Socioeconomic development	Citizen safety
	Economic and political stability
	Cantonal human development index (IDHc)
	Unemployment
	Inequality
	Water availability
	Energy availability
Agricultural production	Soil quality
	Land ownership
	Agrochemical input availability
Quality of the education system	Basic education quality
	Higher education quality
	Trained labour force
	Trained labour force in production, tourism, marketing and business
Basic infrastructure for production and exporting	Laboratories, processing plants, storage units
	LPI index
	Biotechnology infrastructure
Availability of residual biomass	Availability of other types of waste
	Transportation costs
	Availability and access to biodiversity for biotechnology development

Table 2 SC indicators and variables

Indicator	*Variable*
Stakeholders training	Technical capacity of farmers and other VC stakeholders
	Ability to formulate and follow a business plan
	Capacity to manage technology
	Capacity to manage national markets
	Exports capacity
	Product traceability
Business environment	R&T productivity

Table 2 SC indicators and variables (continued)

Indicator	*Variable*
Business environment	SC sustainability
	Association culture among stakeholders
	Alliance options with research and innovation institutions
	Project development among public and private institutions
	Project development among private institutions
	Quality of relationships among stakeholders
Innovation, technology and access	Innovation and access to technology
	Technology availability for bio-products (bio-energy)
	Loss and waste use
	Start-ups support in the agricultural sector
	Ease to obtain innovations and technology information
	Technology availability
	Methods to reduce costs (production, transportation and transformation).
SC biomass	Availability, access and location of residual biomass
	Stability of biomass supply
	Energetic potential (core R&T potential)

Table 3 Institutions indicators and variables

Indicator	*Variable*
Funding	Formal funding to the agrifood and agroindustrial sector (SME)
	Informal funding to the agrifood and agroindustrial sector (SME)
	Funding for bio-productos
	Funding for payments for environmental services
Promotion	SC planning (PITTA)
	Business incubators
	Governmental assessment on national and international product promotion
	Willingness to pay for sustainable products
	State incentives for sustainable public purchases
Education and research	Technical education availability (INA)
	Biotechnology research along the SC
	Business research along the SC
	Knowledge transfer system (to farmers)

The above mentioned variables and indicators were weighted by six experts within each category through a Delphi study. To complete our evaluation, alongside these weights, the evaluation of each variable was composed by a series of questions. An example of the territory evaluation is provided in Table 6. Once weights were assigned, questions were answered to provide a comprehensive evaluation of each variable and each indicator. Possible answers for these questions were: ideal, very good, average, bad and very bad.

As an example, to provide an evaluation for socioeconomic development, depicted in Table 6, a weighted average [equation (1)] was estimated according to the Delphi evaluation and the answers provided for each question.

$$\begin{aligned} Evaluation = ((&safety\ evaluation * possible\ answer) \\ &+(political\ and\ economic\ stability * possible\ answer) \\ &+(HDIc * possible\ answer) + (unemployment * possible\ answer) \\ &+(inequality * possible\ answer) \\ &+(water\ availability * possible\ answer) \\ &+(energy\ availability * possible\ answer)) \end{aligned} \tag{1}$$

Table 4 Legal requirements indicators and variables

Indicator	*Variable*
International norms	Compliance of: Cartagena Protocol, Nagoya Protocol (genetic resources), Nagoya-Kuala Lumpur Protocol, Ramsar sites and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
National norms	National Bioeconomy strategy
	National tourism plan on strategy (sustainable tourism)
	Regulatory framework for ecosystem sustainability
Sector norms	Regulatory framework for: bio-produce, bio-inputs, precision agriculture, environmental recovery and biofuels
Business norms	Existence of a regulatory framework in intellectual property rights that addresses innovations from biodiversity.
	Governmental program for promotion and diffusion of environmental services.
	Organisation of the SC to address common interests

Table 5 Market indicators and variables

Indicator	*Variable*
	Consumer acceptance of biotechnology produce
	Entrenchment of local gastronomy culture
	Trust on the production system of the SC
Sustainability	Productive efficiency and environment sustainability (carbon neutrality, water use, deforestation)
	Demand for sustainable products
	Demand for value-added products
Behaviour	Exports behaviour (of main products of the SC)
	Behaviour of local consumption (of main products of the SC)

If answers for a question were ‘ideal’, then the weight was multiplied by 1, if answers were ‘very good’, then the weight is multiplied by 0.75, if answers are ‘average’, then, they are weighted by 0.5. If answers are ‘bad’, they are weighted by 0.25. Finally, if answers are ‘very bad’, they are weighted by 0, meaning that no points are given to that variable. By doing so, averages now have different scales depending on the weight provided by the experts.

Table 6 Example of variable: socioeconomic development within the category of territory

Indicator	*Variable*	*Delphi evaluation*	*Questions*	*Possible answers*				
				Ideal (1)	*Very good (0.75)*	*Average (0.5)*	*Bad (0.25)*	*Very bad (0)*
Socioeconomic development	Safety	5	Which level of citizen safety can be observed in the rural territories where the SC is mainly located?	Very high	High	Medium	Low	Very low
	Political and economic stability	4	Which is the political and economic stability compared to the best in the country?	Very high	High	Medium	Low	Very low
	Human development index	3	How is the HDIc classified)	Very high	High	Medium	Low	Very low
	Unemployment	4	Which is the unemployment rate?	Very low: lower than 5%	Low: between 6 and 10%	Medium: between 11 and 19%	High: between 20 and 29%	Very high: higher than 30%
	Social inequality	4	Which is the Gini coefficient?	Very low: lower than 0.3	Low: between 0.31 and 4	Medium: between 0.41 and 0.5	High: between 0.51 and 0.6	Very high: higher than 0.61
	Water availability	5	Percentage of inhabitants to water access?	100%	75%	50%	25%	Lower than 25%
	Energy availability	4	How is energy availability'	Good: stable and permanent	Good: permanent but not stable	Average quality	Poor service	No service

Notes: The complete table is available in Spanish. In the Excel sheet, respondents can choose one possible answer from each variable and weighting and estimations of equation (1) and equation (2) are automated.

Table 7 Indicator evaluation

Socioeconomic basic characteristics	2.25	2.72	4.14	5.00	2.28	54%
Agricultural production	2.92	3.37	4.33	5.00	1.63	67%
Education quality	2.00	2.50	4.00	5.00	2.50	50%
Infrastructure for agricultural products	0.75	0.94	4.00	5.00	4.06	19%
Residual biomass availability	3.00	3.46	4.33	5.00	1.54	69%

For each variable, the evaluation was then re-scaled so that a gap analysis could be performed in which variables could be comparable in terms of performance. The re-scaling was estimated according to equation (2). This gap indicates the distance between the current state and the best possible outcome.

$$\frac{\max_{new} - \min_{new}}{\max_{old} - \min_{old}} * \left(v - \max_{old}\right) + \max_{new} \quad (2)$$

To answer all the questions for each variable[1], interviews were conducted from August to October 2020 in the following manner:

1 132 valid questionnaires from small and medium sized farmers, which are predominant in the R&T SC.

2 Nine valid questionnaires from value-added R&T enterprises.

3 515 valid questionnaires from Costa Rican consumers

4 12 in depth-interviews from stakeholders.

Once responses were collected, the above mentioned questions linked to each variable were answered and the analysis was complemented with a consumer questionnaire to analyse consumer behaviour related to fresh R&T and possible value-added R&T produce.

Finally, results were presented and validate in a virtual workshop that included all stakeholders along the SC.

4 Results

4.1 Territory

R&T productions areas in Costa Rica are in Huetar Norte and Huetar Atlantica regions. In these, economic development is based on agriculture, tourism, and natural resources. Low socioeconomic development is common in these regions: high rates of citizen insecurity, unemployment (between 11% and 19%), inequality (Gini coefficient between 0.41 and 0.50), and low rates of human development. According to the Costa Rican Human Development Index, all districts in these areas are classified as medium or low-medium development (PNUD, 2016).

Access to water and energy have been considered very good, almost ideal in both regions, since 100% of the population has access to these services in the country (Mora-Alvarado et al., 2010). In terms of agricultural production, the quality of land is fundamental, and has been classified as very good, not just because the good constant productivity at country level, but because of the superiority of the two main varieties of seed used in the nation for sweet cassava. Access to land is not considered a major problem in these regions, since it's very common that farmers are land owners and lessors and/or tenants – on high demand seasons, they rent additional land to increase their production – however, agrochemical availability has been considered a problem due to bureaucratic procedures, since new agrochemicals for R&T are not registered and cannot be used for these products, affecting productivity and access to new markets. This situation force farmers to use outdated agrochemicals and hamper Global Gap certification, and therefore, EU exports.

Education at a national-scale is relatively good; however, quality and availability in rural regions are bush-league, mainly because higher education or college preparation is limited when compared to the Greater Metropolitan Area. However, Costa Rican public universities are on average in the top 50 in Latin America, which can prepare new professionals to adapt to the current demands of the agricultural sector. The role that higher education and technical schools can play a key for development.

Infrastructure plays a fundamental role in achieving better performance logistics, especially when it comes to exportations. Distribution and access to infrastructure are weak (lack of labs, warehouses, a distribution system for bio-products). Country-wise, there are also significant shortcomings affecting the SC flow, such as access roads, absence of transport rail system or constant logistics unconformities (LP Index).

According to our results (depicted in Table 11), to reduce the gap in these territories, three main aspects should be prioritised. First, mitigation of infrastructure problems; second, strengthen the entire education system, and third: sustainable agrochemical use.

4.2 Roots and tubers value chain (R&T VC)

Cassava yields in Costa Rica (16 ton/ha) are higher than main competitors (Alpizar Arce, 2020), but poor access to outdated inputs and the lack ICTs are disadvantages for R&T farmers, because the access to adequate information for production and market decision-making is null.

Currently, above average costs of Costa Rican cassava compared to other countries is partly due to the large number of stakeholders which take place in the industry. When analysing economic recovery strategies, the most straight-forward strategy would be based on linking small producers with companies, but there are a few governance issues that need to be addressed first:

1. producers do not have bargaining power over the harvest conditions so they establish an informal contract with an external agent who deals with illegal labour force from Nicaragua and becomes responsible for harvesting – farmers lose all their rights over their production
2. most small producers do not have entrepreneurial decision-making capacity, and will not have it in the short-term.

To properly manage a SC, formal organisation, business know-how, and production volume is required to establish serious negotiations with formal firms (abroad).

In terms of the actors 'capacities to accomplish norms and requirements of local markets, Costa Rican consumers (27%) mentioned limited availability of R&T. Regarding the traceability requirements of the chain, there are different types of producers (big-medium-small) which's traceability is hard to ensure because the relations between producers, intermediaries, and entrepreneurs/companies are weak and not formally established.

Business environment has the lowest rate when compared to other indicators in the VC. Crops profitability is seriously compromised by low prices, particularly in second and third quality products (especially during the Covid-19 economic recession). This occurs because of the lack of an established business structure that advocates for chain improvement, little added value, deficiency of development and innovation projects between private actors, the limited relations between actors, and the absence of public-private alliances.

With respect to innovation and technology, Costa Rica has developed some research in the agricultural, biotechnological, and food sectors, however, the implementation of these does not fully reach R&T farmers (Vargas, 2020). Concerning the biomass of the chain, there is great potential for its use in several ways, partly because of the high in-farm losses. It has been estimated that around 30% of cassava is not harvested. This situation occurs primarily when premium quality prices are low (below 5,000 colones (8 USS) per 46 kilograms of fresh product).

When estimating losses, Okudoh et al. (2014) indicates the following:

a Ñame: $\left(\frac{1{,}114.1}{1{,}243.9} = 0.89\right)$ losses account for 11%.

b Ñampí: $\left(\frac{1{,}519.1}{1{,}642.7} = 0.92\right)$ losses account for 9%.

c Tiquizque: $\left(\frac{1{,}211.2}{1{,}511.2} = 0.80\right)$ losses account for 20%.

Additionally, Costa Rica has 9,411,8 hectares dedicated to cassava production, which account for 589 tons; if 30%[2] is lost, then losses would account for 45,177 tons.

These losses are an opportunity so, when considering bio-ethanol production and water footprint (WF), cassava has a 158 WF (m^3/GJ) (Okudoh et al., 2014). With one tone of fresh cassava (considering 30% of carbohydrate content and 80% fermentable sugars into dry matter), 280 litter of 96% alcohol could be produced. However, technology for processing, food security and lack of legal regulations for bio-ethanol production are the main constraints for bio-ethanol production (Cassava Archives | Page 12 of 12 | IITA, 2005).

Regarding the analysis of the chain, the highest gap is the business environment, and the one with the highest potential is biomass use. Uses of losses are considered in two dimensions:

1 the use of bio-energies should come from leaves and stems, which are not used for human consumption

2 given the outstanding quality Costa Rican cassava, its nutritional values and its potential to collaborate with the country's food security, products should focus in other alternatives rather than bio-energies.

For example, in value added products that expands the life cycle, since fresh cassava must be processed in a maximum of 48 hours once it has been harvested.

4.3 Support institutions

Public institutions related to agriculture have promoted productive transformation through funds. These compete with diverse forms of informal financing, which mostly based on trust relationships between actors. Funds are mainly used to buy inputs such as agrochemicals, raw materials or equipment, being common that small farmers are the main users of this kind of resources, meanwhile, slightly bigger organisations (like associations or companies), advocate for formal financing. Another source of funds can be acquired though the Costa Rican National Bioeconomy Strategy (issued in August, 2020), because it provides funds to encourage biotechnology and sustainable development projects.

Within the National Bioeconomy Strategy, 'Small Donations Programs' sponsored by the UNDP offer non-reimbursable seed capital (up $50,000) for community projects that protect and conserve the environment. The 'non-waste Centroamérica' program funds innovative solutions to reduce losses and waste in food chains. Also, the Costa Rican National Bank funds biotechnological companies through the 'BN PyMe Verde' program, The 'Popular Bank', finances investment for community development, and finally, Fundecooperación, funds small companies who are not ready for the traditional banking system. These options indicate that the country offers multiple sources to seek expansion and value-added improvement to develop innovatively high-value bio-enterprises. However, small farmers usually lack the formality needed to access these options (Alvarado-Hernández et al., 2016), since usually manage their productive systems in a very informal manner; pushing a gap in the agricultural financing sector.

Since 1996 many land owners with primary or recovered forest have used the payment for environmental system to generate sources of complementary income through environmental conservation and agriculture. By 2019, Fonafifo[3] had given 103 contracts to female forest owners, 248 deals for male forest owners, 19 agreements for indigenous land owners and 362 contracts to private firms, representing more than 14 billion colones in just one year (Fonafifo, 2020).

In regards of promotion and institutional support, the outcome was very positive; still there are specific opportunities for improvement which are vital to enhance its full potential. The country has different public and private research centres that develop investigation and carry value chain analysis; but results do not always reach the correct beneficiaries (Blanco Picado, 2018).

Regarding sustainable tourism, which in inevitably linked to agriculture, Costa Rica has support institutions with extensive experience and considerable knowledge in promoting green tourism. This has allowed the proliferation of small companies that are engaged in conservation, sustainability, and promotion of the country's flora and fauna. Through the Costa Rican Tourism Institute (ICT) several chambers, projects, and small businesses have been successfully formed. To show the scope of ICT, only in 2019, they registered 3,741 lodging establishments, between 0–5 stars, and at least 57,786 rooms available for tourism purposes. This numbers represented a direct workforce of 170,870 people dedicated to tourist activities, and 512,609 people between direct and indirect workforce, which is about a 20.8% of the total country workforce (ICT, 2021).

Finally, education and technology were classified as excellent since the National Institute of Learning (INA), Costa Rica University (UCR), National University (UNA) and the National Institute of Technology (TEC) focus on training human resource at different levels, and simultaneously carry out biotechnological research. Agronomic research, seed improvement, versatility and better use of raw materials are currently carried out by these institutions. Precision Agriculture Centre, located in Guanacaste, works on productivity improvements of small and medium producers. Its main tasks are the measurement of inputs in plantations, experimental designs, soil analysis to estimate land requirements, chemical analysis, measurements with drones, among others (Earth, 2018). There is no widespread use of these techniques, and R&T producers usually have severe deficiencies related to management, outdated technological packages, or poor negotiation capacities which translate into a large path towards improvement.

Despite all the previous aspects explained, the R&T chain is moderately organised in the Huetar Norte region by the Chamber of R&T, since SC actors can be clearly identified, however, the significant role that intermediation actors play in the process of marketing, makes very difficult to establish functional alliances within organisations.

4.4 Legal

The Costa Rican regulatory framework concerning to the application of international regulations on compliance with the adherence to protocols in the biotechnological field, is extensive. The government has ratified the country's position on: commercialisation of genetically modified organisms, biotechnology security, the use of phylogenetic resources for food and agriculture.

Specifically, Law 8536 of 2006 regulated the administration of genetically modified organisms, in accordance with the Cartagena Protocol. Regarding management and access to existing biological and genetic resources, the country has also taken a very solid position, through the convention on biological diversity (CDB) and the Nagoya Protocol. Costa Rica ratified the CBD over Law 7416 on June 30, 1994, with the main goal of preserving biodiversity, making sustainable use of its components and being part of the future benefits derived from possible uses and applications (SCIJ, 2020a).

As for the Nagoya Protocol, it was signed by Costa Rica in 2011 and it's currently in the process of ratification meanwhile the Nagoya – Kuala Lumpur Protocol is still in the process of adoption. This protocol regulates liability and compensation in case of damage due to misuse of biodiversity; it considers hazards of cross-border movement of genetically modified organisms (Madriz, 2012).

Costa Rica has more than ten Ramsar declaration sites (mangroves, national parks, wetlands, among others) which are denominations of international importance due to biological richness and the role of wildlife refuge. Additionally, the countries possess three sites called 'Natural World Heritage' (SINAC, 2020).

The Washington Convention, also known as the Convention on International Trade in Endangered Species of Wild Flora and Fauna is part of the legal framework of Costa Rica since October 30, 1974 thanks to Law 5605 that guarantees protection, sustainability, and traceability of flora and fauna (SINAC, 2020).

The indicator on *general regulations at the national level* highlighted the National Bio-economy Strategy, which through different public-private alliances and development projects, promotes bio-enterprises on aquaculture, biotechnology, agriculture, sustainable tourism, and industrial reconversion. The scope of the Costa Rican bio-economy' potential is vast, since allows the creation of links with most productive sectors, and mainly with the tourism, which uses the National Tourism Development Plan of Costa Rica 2017 – 2021, to enhance the concept of sustainable tourism in the country. This approach embraces the environmental resources as the basic element of economic growth, under the premise of maintaining ecological processes and preserving natural resources (ICT, 2017). Additionally, Costa Rica's approach to sustainable tourism is based on maintaining socio-cultural authenticity by authorising communities to ensure viable economic activities, reduce poverty and create employment trough sustainable tourism experiences (ICT, 2017).

In regards of specific legal regulations of the agricultural sector, the agricultural organic production system is essential, since the country has done significant progress towards guaranteeing attractive options to the producers to enter market niches. Law 8542-*Law for development and promotion of organic farming grants organic producers*, provides incentives such as the 'regime of agricultural environmental benefits' which recognises organic productions as providers of environmental services, and therefore subject to payments for such actions. Also, it provides financing support with low-interest rates and tax exemption (SCIJ, 2009).

Environmental bioremediation consists of recovery processes of contaminated sites by stimulating microorganism to degrade pollutants in biomass and carbon dioxide (Ulloa Leitón, 2018). Even its regulation in Costa Rica is in early stages, many farmers make use it to treat soils in a sustainable matter, seeking less land degradation and environmental impact without high technological or structural investment (Ulloa Leitón, 2018). From an academic/scientific scope, there is greater regulation about bioremediation, since the National System of Conservation Areas (SINAC) and the National Commission for Biodiversity (CONAGEBIO) (for their acronyms in Spanish) are the public entities capable of granting authorisation to carry out research for the purpose of collecting scientific samples, managing wild populations, bio-prospecting or commercial use; all attached to the limitations of the Wildlife Conservation Law (Law 7317) and the Biodiversity Law (Law 7788).

Lastly, the country's regulation for biofuels, although exists, its application is very limited and its operation is highly complex at a technical and legal level. From the legislative point of view, Costa Rica has the Biofuels Regulation, Decree 35091 –MAG-MINAE, which specifies the scope and limitations of the production and use, but, is not currently available (SCIJ, 2020b) and biofuels are not produced at least in large scale. Waste from R&T has more commercial value from the agro-industrial point of view, than biofuels, especially when production is not regulated and the administration of fuels is a monopoly of the Costa Rican Oil Refinery (RECOPE, for its acronym in Spanish).

Also, RECOPE is working with the National Biofuels Program to develop a research program to determine the feasibility of adding ethanol from corn and sugar cane to gasoline-and perhaps R&T-, and at the same time reduce the impact on the environment, mitigate the climate change, and transition to the biofuel industry in the medium-long term (RECOPE, 2020). This program does not have immediate implications on the national energetic, which in regards to electric production is 100% renewable; nonetheless in 2016, 60% of the country's consumption derives from oil (petroleum).

The last group of variables considered within the area of legal analysis is business regulation of the agriculture sector, where we found opportunities for improvement such as intellectual property rights and the use of biodiversity. Currently, exists legislation that covers these issues, such as Law 8039 on procedures for the enforcement of intellectual property, or Law 8149 of the National Institute for Innovation and Transfer in Agricultural Technology (INTA, for its acronym in Spanish), but Law 8039 does not address agriculture specifically, and does not encourage the new technologies, but only protects the existing ones (SCIJ, 2000).

Meanwhile, Law 8149 refers mainly to the obligation of the institution to register industrial property or new plant varieties. Nevertheless, not all actors involved in the R&T sector has a direct relationship with INTA to access new information or research results.

4.5 Market

R&T market is composed of exports, Costa Rican consumers and government purchases. To address market behaviour, our sample size was mainly young (56.7%) from 18–35 years, 15.7% between 36 and 45 years, 14.2% from 46 to 55 and 13.4% older than 55 years. Also, our sample has higher education than country averages: 25.5% are currently enrolled in a university (which is normal, considering the sample's age), 41.9% have completed their university degree and 24.1% have completed a postgraduate degree. Income can be observed in Table 8.

Table 8 Monthly per capita income

Ranks	*Percentage*
Less than 250,000 ($408)	26
Between 250,001and 500,000 (–$815)	15.7
Between 500,001 and 1,000,000 (–$1,629)	24.3
Between 1,000,001 and 1,500,000 (–$2,444)	17.7
Between 1,500,001 and 2,000,000 (–$3,258)	7.2
Between 2,000,001 and 2,500,000 (–$4,073)	4.1
More than 2,500,001 (> $4,073)	4.9

Note: Exchange rate: 614 colones/$1.

Regarding geographic location, most of our sample (94%) lives in the GMA (compared to 45% of Costa Ricans). In addition, income ranks can be observed in Table 9. The survey was carried out virtually and young people have greater access to technology, so it is expected that there will be high percentages of younger people. Likewise, there is a correlation between youth and lower income, so even though the education level of the respondents is high, the income is lower than average, since probably, students are still (partly) dependent on their parents. With regards of liking of different R&T, results are shown in Table 9.

Cassava, sweet potato, ginger and arracacha are the most liked products by Costa Ricans. On the contrary, only around 50% like yampee, turmeric, orange sweet potato and nyampi. There are important percentages of Costa Ricans not liking these products, which calls the attention of value-added products as alternatives to increase consumption. Reasons for buying these products include: flavour (36%), nutritional properties (28%), culture and tradition (27%) and lastly due to their low price (8%). In cases in which there is no consumption most consumers addressed availability of these products in local supermarkets (27%) as well as lack of knowledge on how to prepare them (22%). To address possible value-added products, and potential consumption, Table 10 shows though a five-point Likert scale, levels of interest in new produce derived from R&T.

Table 9 Costa Rican liking of R&T

R&T	*Yes*	*No*	*DN*
Cassava	97%	3%	0%
Sweet potato	86%	13%	1%
Orange sweet potato	58%	13%	29%
Nyampi (Dioscorea esculenta)	55%	28%	17%
Taro (Colocasia esculenta)	74%	19%	7%
Tiquisque (Xanthosoma sagittifolium)	67%	25%	8%
Turmeric	55%	24%	20%
Ginger	83%	15%	2%
Arracacha (Arracacia xanthorrhisa)	77%	16%	6%
Yampee (Dioscorea trífida)	41%	21%	37%

Note: DN: does not know the product.

Table 10 Degree of interest in new R&T value-added products

Possible answers	*Flour*	*Frozen ready to consume products*	*Chips*	*Pasta*
Very interested	12%	18%	33%	13%
Somewhat interested	20%	17%	25%	32%
Neutral	41%	24%	24%	32%
Not very interested	20%	25%	14%	15%
Not at all interested	6%	16%	4%	7%

Chips are the only widely offered product in the country derived from R&T, which explains why these percentages are significantly higher than other products. Although further information and analysis of consumer behaviour is needed, there is a positive outlook regarding consumption.

Table 11 General SC evaluation (see online version for colours)

Indicator	*Variables*	*GAP*	*%*
Territory	Socioeconomic basic characteristics	2.28	54%
	Agricultural production	1.63	67%
	Education quality	2.50	50%
	Infrastructure for agricultural products	4.06	19%
	Residual biomass availability	1.54	69%
R&T SC	Stakeholder’s training	2.46	51%
	Business environment	3.06	39%
	Innovation and technology	2.52	50%
	Biomass of the SC	0.39	92%
Support institutions	Funding	0.90	82%
	Promotion	1.83	63%

Table 11 General SC evaluation (see online version for colours) (continued)

Indicator	*Variables*	*GAP*	*%*
Support institutions	Education and research	0.97	81%
Legal	International norms	0.37	93%
	National norms	0.42	92%
	Sector norms	2.50	50%
	Business norms	2.92	42%
Market	Consumer acceptance of biotechnology produce	2.5	50%
	Entrenchment of local gastronomy culture	2.5	50%
	Trust on the production system of the SC	0.0	100%
	Sustainability	2.5	50%
	Behaviour	3.12	38%

In regards of Table 11, lack of infrastructure in the main weakness identified in the R&T SC. This gap in infrastructure is associated with higher production and logistics costs as with higher waste (Negi and Anand, 2016), which is aligned results from Trienekens (2011), in which weak infrastructure and institutional voids are identified as major constraints for SC upgrading. Business environment as well as consumer behaviour, as was stated before also mandatory for SC performance and are the three main challenges of the R&T SC in the country.

5 Conclusions

Based on the best and worst performance indicators, infrastructure, business environment and consumer behaviour are the largest limitations according to our SC analysis. On the other hand, waste, although it is a major problem along the SC, it is also the best short run path to improve productivity, since there is plenty of R&T production, value added options and legislation to address sustainability.

Waste is a major sustainability problem and it is related not only to overproduction but to the R&T governance structures and low prices (in Covid-19 times). Potential for using this waste in sustainable alternatives require institutional support, which is a strength in most of Costa Rican legislation. The bio-economy strategy issued in 2020 is a possible and verifiable option for sustainable development, however the strong legal frameworks to support agriculture is seriously diminished when analysing the commercialisation of bio-inputs and registration of agrochemicals, since many of the technological packages used in agricultural production, especially R&T, are strongly outdated, compromising agricultural competitiveness and hindering SC development. This situation has forced the government to create a decree to put the state Phytosanitary Service in charge of regulation, despite this effort, there were no improvements in the process of speeding up the registrations of new products, forcing producers to add high agrochemical applications just to achieve expected productivity, which causes substantial environment impact (Chacón 2018).

The abovementioned situation is being addressed by the Chamber of R&T which seems to be changing the governance structure along the SC. The R&T chain's organisation mechanisms show that there is a certain level of formal organisation, but not across all actors of the chain. From the producer's point of view, it's common to find organised groups looking for major benefits as associations or cooperatives, to protect themselves and their harvests, but these figures often fail to establish agreements with major stakeholders due to strong intermediation and lack of farmers' commitment.

To tackle waste, consumer behaviour is also important, since value added products or increasing fresh consumption can be part of addressing economic growth (for traditionally poor production regions) and improving food security. The percentage of R&T in institutional purchases could increase R&T consumption, considering these two-sided positive effects since R&T are also relatively cheap. SCM is not common in Latin American agriculture, especially of marginalised products such as R&T; nonetheless, the potential for development also seems to be coupled with the development of Public-Private partnerships for research, development and market access.

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Notes

1 Because of Covid-19`s pandemic, all interviews were performed trough zoom meetings or by phone interviews.

2 According to 2020's farmer's interviews.

3 The National Forest Financing Fund (Fonafifo, for its acronym in Spanish) is the main institution in Costa Rica in charge of payments for environmental services.