Bioeconomy opportunities for four Colombian regions

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Instituto Humboldt Colombia

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GROW Colombia

Bridge Colombia

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1. Executive Summary

In the light of Colombia's highly biodiverse environment, the stock of wealth or natural capital that this represents provides an excellent basis for a bio-economy development path. Various definitions of bioeconomy exist, but the one focused on in this report merges bio-resource (strong sustainability) and biotechnology paradigms (weak sustainability) to enable a development path that recognizes regional and local diversity factors. The overall aim is to promote the production and use of knowledge on biological resources, processes and products e.g food, fibers, and health products among others. Land ownership constraints, funding levels, protection of intellectual property rights and overall employment and post-pandemic impacts, all require government attention and action to better enable bioeconomy progress in Colombia.

In this report, we review the macroeconomic principles which should underpin bioeconomic progress, as well as the indicators required to assess such progress. Regional scale analysis is used to identify baseline conditions (via asset checks and cluster analysis) and barriers and opportunities for future bioeconomy investment programmes. This initial evidence base is supplemented by data derived from an online survey of local stakeholders. The success of any bioeconomy strategy will be conditioned by both the development of an international governance regime to enhance the protection of intellectual property rights including the Access and benefit-sharing (Nagoya Protocol), and the fostering of greater stakeholder coordination, as well as national to regional stakeholder engagement and coordination resulting in a more established stakeholder network.

In terms of macroeconomics, an extensive green investment portfolio needs to be stimulated to kick start the economic development process and its transition to sustainability. This large injection of money into the economy is not without its dangers and three particular indicator issues need to be closely monitored: deficits measured as a percentage of GDP need to be below or at the rate of economic growth; the development path created should be in line with sustainability objectives; and the investment programme should aim to reduce inequality in incomes /wealth. Overtime, the green investment programme will need more than initial public and private expenditure stimuli, and revenue raising via green or other forms of taxation will need to be considered.

Monitoring progress will require the adoption of the circular economy concept in which the impact of the bioeconomy investments on GDP and the consequent effects on the national capital stock (physical, natural human and social components) are accounted for. The circular economy concept and its growth over time that we have in mind, sits in a 'safe' and 'fair' space between two boundaries. An environmental boundary to protect against significant pollution and resource deletion effects; and a social boundary which guards against loss of wellbeing/culture and increases in inequalities. A pragmatic approach to the national system of economic accounting is also required, one which encompasses a range of economic growth, wealth and wellbeing parameters. In this report we advocate the use of the CAN (Complementary Accounts Network) to provide the necessary monitoring capability.

Individual bioeconomy projects, policies or courses of action will need to be appraised in terms of their economic efficiency, eco-efficiency (e.g. carbon footprint reduction) and effectiveness, costs and benefits. Careful policy instrument coordination will also be necessary to manage efficiency and inequality trade-offs and to overcome existing regulatory failures.

In this report, we review the macroeconomic principles which should underpin bioeconomic progress, as well as the indicators required to assess such progress.

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María Paola Sánchez, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt

Some of the costs may be the result of unintended consequences such as, for example, so-called 'rebound effects' from increased land use efficiencies. A switch to more productive land use such as from extensive cattle ranching to silvo-pastoral systems could in certain circumstances lead to an expansion in land use and a consequently increased threat to intact biodiverse lands such as forests.

Four case study regions, Antioquia, Valle del Cauca, Coffee region and Orinoquia, were chosen for the baseline asset check and cluster analysis, together with a stakeholder/network analysis in order to assess a sustainable bioeconomy potential. The cluster analysis was partitioned into economic, social and environmental categories. Five 'economic' cluster areas were found: a service-led highly developed cluster; a balanced development cluster; the coffee triangle cluster; a rural development cluster and a primary sector-led cluster. The five 'social' clusters were made up of a core central area of Colombia with high levels of education and innovation potential, together with lower levels of poverty. Outside of this core was a more peripheral cluster with higher levels of poverty and lower innovation diffusion. The five environmental clusters more or less mirrored the natural regions of Colombia but with outliers given the mega diverse character of the country and the concentration of human footprints in given areas. This baseline asset check was complemented by a summary of the historical trends in the regions, compared to the national socio-economic and cultural change picture.

The stakeholder survey (167 usable questionnaires) indicated that around 75% of respondents were engaged in biodiversity sectors such as bio-research, ecotourism and forest products, or in agriculture or green chemistry and ecological engineering. Survey respondents ranked bio-research and development as the most important sector for future development in Valle del Cauca, Antioquia and the Coffee Zone. Biodiversity and ecosystem services were the top priorities in Orinoquia. When asked to list the most important needs for a sustainable future bioeconomy in Colombia several economic requirements were highly ranked: the existence of bioeconomy value chains; efficient public infrastructure; access to R&D capability; improved governance system and new targeted economic and financial incentive instruments. The social needs included better education and workforce training, the existence of creative hubs, and more public market acceptance of bio-products. Finally, in the environment context the continued presence and protection of highly diverse ecosystems and habitats was considered crucial.

Sustainable bioeconomy investments will depend on both local push and a regional/national pull, and need to be enabled through appropriate financial incentives and extensive stakeholder networks and partnerships. The data driven (cluster and survey) analysis in this report revealed both opportunities and challenges for the further development of bioeconomy. The use of both types of analysis must be buttressed by an effective and efficient knowledge transfer process. Key to the success of such a transfer are expanded knowledge hubs and truly participatory networks. These networks must bring together collaborating entities which encompass private business, financial organisations, NGOs and government (local to national). Overall, the transition to a more bioeconomy based development path in Colombia needs to be both 'measured' (taking full advantage of the evidence base anchored to a comprehensive capital asset check and stakeholder preferences) and regionally diversified building on in situ natural resource endowments. ▲

The baseline asset check, cluster analysis and stakeholder/network analysis were developed in Antioquia, Valle del Cauca, Coffee region and Orinoquia in order to assess a sustainable bioeconomy potential.

2. Introduction

It is assumed that the overarching policy goal in Colombia is sustainable development, enabled through a sustainability pact, "that seeks an equilibrium between production, development and environmental conservation, that stimulates potential new economic activity, and ensures natural resources for future generations" (Departamento Nacional de Planeación, 2019). Under such an approach contemporary society is required to pass on to future generations a total capital stock (physical, human, social and natural capital) that is as good as, or better than, that received. Given Colombia's highly biodiverse environment (more than 58,000 registered species) the natural capital component of the total capital stock has been recognised as a strategic national asset and an excellent foundation for a bioeconomy development path. The Colombian Government aims to get 10% of its GDP through this strategy by 2030.

In principle, the development of bioeconomy investments represents an opportunity for many countries to enable a sustainable growth strategy. However, different definitions of bioeconomy exist, and their specific characteristics may lead to different development strategies. So-called bio technological strategies aim to first and foremost support conventional (GDP-focussed) economic growth and job creation, by specifically leveraging biotechnological innovation and market development. For these types of strategies, R&D spending both privately and publicly funded, are the key drivers, and their success is crucially linked to global economic conditions. Alternative visions of a bioeconomy driven development seek to combine economic progress with a stronger emphasis on sustainability criteria. These forms generally require a broader, more interdisciplinary knowledge base, as well as greater attention to land uses and to biodiversity conservation and management. Bugge et al. (2016) report that bioeconomy projects that aim to protect biodiversity and avoid soil degradations may be labelled 'bio-ecological' investments. These projects usually hinge around switches to high-quality products that are integrated within a clearly defined territorial identity, take into account ecological interactions and involve circular economy principles. Therefore, the generic term "bioeconomy" may be very broadly taken to refer to any industrial and economic sector that produces, manages and otherwise exploits biological resources and related services (Sasson and Malpica 2018; Haarich 2017). Consequently, there is a fundamental need to define more precisely what a given bioeconomy vision entails and what its sustainability credentials ('weak' or 'strong') are.

'Weak' sustainability supports a constant capital stock rule but allows for technical change and innovation that opens up a wide range of substitution possibilities between the different components of total capital, including natural capital. So, it is the value of the total capital stock that has to be maintained or increased over time. 'Strong' sustainability on the other hand is less optimistic about technical progress and stresses the need to fully conserve and protect so-called 'critical' natural capital assets such as biodiversity and other life- supporting processes. Therefore, the constant capital rule is viewed in value terms in the 'weak' sustainability perspective and in bio-physical terms in the 'strong' sustainability perspective.

The two main versions of bioeconomy fit more or less into the two sustainability paradigms, with biotechnology sitting most easily into 'weak' sustainability and bio-resource in the 'strong' sustainability camp. But these sustainability

Alternative visions of a bioeconomy driven development seek to combine economic progress with a stronger emphasis on sustainability criteria.

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positions are best viewed as part of a spectrum without sharp boundaries. In the bioeconomy context, there is a crossover between technological innovation and conservation known as “assisted evolution” (Kolbert, 2014). What is proposed is that humans intervene to speed up evolutionary change in target species. Experiments have included crossing different species of coral in order to test their tolerance to heat stress for eventual reintroduction into reefs; or gene editing CRISPR to enable the passing on of a given species trait.

The definition adopted in this report is:

> Bioeconomy refers to the production, use, and conservation of biological resources, including related knowledge, science, technology and innovation to provide information, products, processes and services across all economic sectors, towards a sustainable economy (Global Bioeconomy Summit Communiqué, April 2018, Berlin, Germany). The bioeconomy approach is framed and appropriately adjusted to the SDGs, since it encompasses the environment (natural world, biological resources and their interactions with human activity), as well as biotechnology (use of organisms, processes, or biological systems for obtaining goods and services) and, additionally, it is transversal, regional, multi- and interdisciplinary.

This definition encompasses the bio-resource and bio-technology paradigms and aims to promote sustainable development, which recognizes the regional and local diversity in economic, social and environmental assets.

In this report, we review the key macroeconomic principles relevant for bioeconomy initiatives, propose supplementary monitoring tools to support the implementation of bioeconomy initiatives and empirically assess the economic, social and natural assets of the Colombian region with a multi-dimensional statistical analysis. We subsequently analyse (cluster analysis) indicators of economic, environmental and social conditions and changes at the regional level to identify the barriers and opportunities for further bioeconomic investments. The data-driven evidence is finally complemented with the results of an online survey with local stakeholders to capture their opinions on viable bioeconomy projects.

Sustainable bioeconomy investments will depend on both a local push and a regional/national pull with appropriate financial and networking partnership mechanisms. The cluster analysis and stakeholder survey results reveal both opportunities and challenges for further bioeconomic development. Our analysis highlights the importance of the knowledge transfer process and the need for expanded knowledge hubs. The transfer process will require a comprehensive capital asset check (e.g. via cluster analysis) and more formal and effective networking arrangements bringing together collaborative partnerships encompassing private firms, financial agencies, NGOs and government (local /national). We therefore recommend that the transition to a more bioeconomy based development path in Colombia needs to be both measured (informed by as good as is feasible indicator cluster database and advice from expanded network partnerships) and regionally diversified. ▲

We recommend that the transition to a more bioeconomy based development path in Colombia needs to be both measured (informed by as good as is feasible indicator cluster data base and advice from expanded network partnerships) and regionally diversified.

3. Bioeconomy and the macroeconomic perspective

A bioeconomy strategy requires an enabling portfolio of green investments targeted at resource/energy use, efficiency gains and waste reduction, together with health, education, environmental and cultural assets improvement. It is a form of Green Keynesian macroeconomic thinking (Harris 2019; Pollin 2018), which aims to stimulate economic activity rather than supporting a 'de-growth' path (Daly 1996; Kallis 2018). Critics of Green Keynesianism worry that its short-term stimulus benefit effect may also generate costs such as increased deficits and debt with inflationary consequences and even longer-term sovereign debt crises. It may also be the case that high levels of deficits and debt will constrain infrastructure investments e.g., health, education etc.

As macroeconomic objectives, three broad indicators need to be born in mind:

- *DEBT MANAGEMENT:* deficits measured as a percentage of GDP need to be kept below or at the rate of growth, while allowing for short run green expenditures and/or tax cuts.

It is also worth bearing in mind that a de-growth policy would require strict balanced budgets through time;

- *SUSTAINABLE DEVELOPMENT:* on sustainability grounds, a constant capital rule must be observed in either 'weak' or 'strong' form, together with a precautionary approach to 'critical' natural capital protection, thresholds and tipping points;

- *DISTRIBUTIONAL EQUITY AND FAIRNESS:* infrastructure investments should be tailored to inequality reduction through health and other well-being enhancing expenditure.

At the macro-level (and in line with the circular economy concept) natural, man-made, social and human capital will condition and determine the variety of bioeconomy strategies available for a country (column 1 Figure 1) and in return bioeconomy initiatives will impact GDP performance and a suite of indicators including natural capital stocks and service flows. Natural capital accounts and wealth accounts can play a key role in monitoring the success or otherwise of the circular economy (Talberth and Weisdorf 2017; Turner et al. 2019). It is paramount that ex-ante and ex-post measurements support the design and development of bioeconomy projects.

Figure 1 illustrates a 'Complementary Accounts Network' (CAN, Turner et al. 2019) which encompasses a suite of indicators

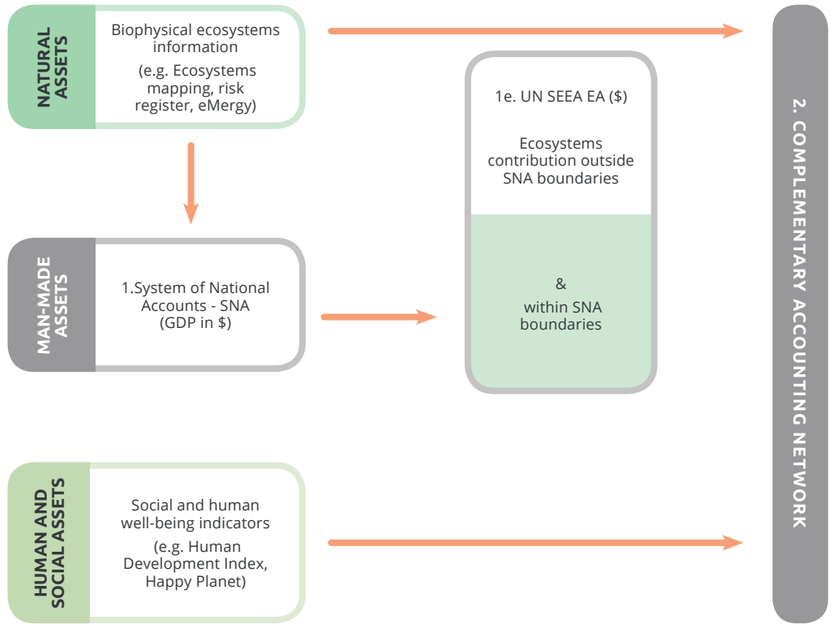

Figure 1
Complementary Account Network to monitor bioeconomy initiatives (adapted from Turner et al 2019)

alongside GDP that can monitor the effect of bioeconomy initiatives on SDG objectives and the country's welfare pathway. The strength of CAN is to consistently account for economic performances, primarily measured by GDP, along with environmental and social effects. The CAN is developed to be consistent with the UN SEEA EA (2021) guidelines but accommodates a wider set of environmental and social indicators which might be the leading effects of bioeconomy projects. Furthermore, the CAN is applicable at the national as well as local level and offers a degree of flexibility to support the decision makers to monitor macro-indicators.

At the level of individual projects (micro-scale indicators), policies or courses of action, there will need to be an appropriate set of appraisal criteria, indicators and implementation measures focused on resource efficiency and eco-efficiency gains. Measures will include, among others, carbon reduction instruments (e.g., taxes, cap and trade, payments for carbon storage); soil nutrient and carbon retention means; grazing land quality enhancement; sustainable yield management of renewables supported by quotas; water conservation and biodiversity conservation and management measures (low-cost credit, payments for ecosystem services, tree planting, ecosystem restoration).

Given that a bioeconomy strategy encompasses multiple policy objectives it is worth considering a well-established piece of economic policy guidance known as the Tinbergen Rule (Tinbergen 1952). The rule states that at least *x* independent policy instruments are required to successfully achieve *x* independent policy targets (GDP, employment, water quality improvements, carbon reduction, etc.), except in circumstances in which all targets are independent and instruments are neutral, i.e. they only affect the designated target. Instruments can either be classed as complementary or conflicting. Just to take one example, a carbon tax designed to reduce carbon footprints is a regressive tax and therefore will conflict with any inequality reduction target. Policy instrument coordination is therefore very important if efficiency and effectiveness gains are to be realised. In the carbon tax case, rebates could be offered to lower-income households.

A green investment programme will also need to be supported over time by more than public/private investment expenditure. Some other form of revenue raising will also be required from, for example, more progressive income tax, increased corporation tax and maybe a "Tobin" tax on speculative trading on international financial markets.

Overall, a green investment stimulus package must be designed to fit into an expanded circular economy approach.

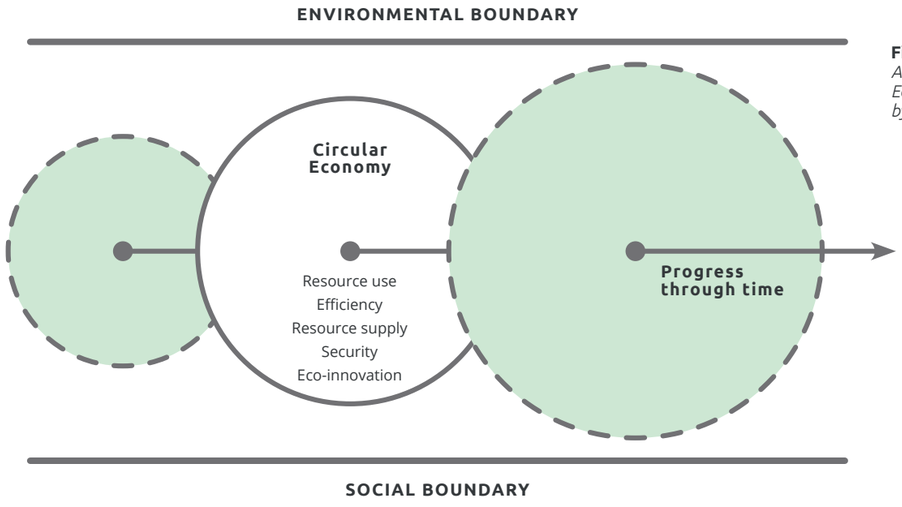

Figure 2
An expanded Circular Economy constrained by boundary conditions

3.1 An Expanded Circular Economy concept

Once a bioeconomy initiative is designed, it should carefully fit within Circular Economy principles to optimize the impact on natural and social assets. Our Expanded Circular Economy concept is constrained by two 'boundary' conditions: an outer environmental boundary and a lower 'social floor' boundary linked to a maximum acceptable level of wealth inequality, and minimum acceptable level of deprivation (see Figure 2)[1].

The Circular Economy sits between these boundaries in a space that is 'safe' and 'fair'. These boundaries serve to warn society about any economic growth that risks breaching thresholds or tipping points that may produce sudden and/or irreversible environmental state changes and damage costs, which combine to threaten national and eventually global systems resilience.

The social inequality boundary also has an economic dimension. There is a strong case to argue that gross inequality carries both an economic and a social price and that these are interwoven. Growing inequality is associated with growing inefficiencies and less productive economies, which also display increased stress, poor health, and low levels of social mobility. The Expanded Circular Economy approach allows for a broader vision of economic progress, which produces sustainable economic development and increases in societal well-being.

Our Expanded Circular Economy paradigm is more comprehensive than some previous applications of this concept. Investments in green projects eventually leading to system-wide innovation will be necessary, and the transition needs to be underpinned by systematic assessment of environmental and social consequences of economic changes. At the sector and/or individual project level there is a need to deploy a pluralistic approach to an appraisal which extends beyond the conventional economic cost-benefit approach.

1 The standard Circular Economy is expanded to include plural values in nature as well as fair distribution of benefits across current and future generations. Therefore, economic growth is bounded by social and environmental limits.

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Francisco Nieto Montaño, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt

3.2 Unintended consequences of bioeconomy initiatives

In some circumstances, policy measures that aim to improve environmental quality, efficiency and productivity may instead lead to unintended and detrimental environmental outcomes as well as social and economic externalities[2]. Measures geared to promoting bioeconomy are no different in this respect, and these aspects need to be carefully considered in the design phase.

A first unintended, detrimental consequence of conservation measures can occur when individuals anticipate the introduction of such measures, and their potential to limit profitable opportunities in the future may lead to an acceleration of habitat destruction and biodiversity loss ahead of the measures being introduced or implemented. These 'anticipation effects' need to be carefully considered before any significant policy announcement, especially when the lead time to the measures coming into force is long and the potential loss is irreversible, as is the case for unique ecosystems and vulnerable species.

A second possible effect that tends to be overlooked, especially at subnational scales, refers to the possibility that limiting destructive practices such as deforestation and poaching in one region may simply lead the perpetrators to move across the border in a different jurisdiction, thus only relocating the environmental damage rather than achieving a long-term sustainable outcome. This phenomenon, known as 'leakage', requires a holistic, overarching view of the impacts of the policy changes being sought and a robust engagement with all stakeholders.

A final and significant risk emerges when more efficient means of utilizing natural resources are developed and deployed, for example when agricultural productivity increases due to new varieties and practices being introduced. While one could expect such change to lead to a reduction in the use of natural resources – after all, the same bang can be achieved with fewer bucks – in reality a large body of research (Kleinschmit et al 2017) has shown that by making the use of the resource more profitable, increases in efficiency may instead lead to an increase in its aggregate use. This idea was

2 Policies targeting bioeconomy strategies or environmental efficiency objectives even if guided by strong sustainability principles can always trigger unexpected consequences on other natural capital assets, as well social, human and economic capitals.

first mooted by Jevons (1865) in his classic discussion about the consequences of the increased efficiency of the steam engine:

> "It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth. [...] Whatever [...] conduces to increase the efficiency of coal, and to diminish the cost of its use, directly tends to augment the value of the steam-engine, and to enlarge the field of its operations."

This is well-known as the 'Jevons' Paradox', which leads to a 'rebound effect': -ceteris paribus- a more efficient coal-fired steam engine implies a reduced input demand. The more attractive engine, however, is put to more widespread use, and steam and coal use decrease less than would be the case without this additional change – the polluting emissions that would have been falling 'rebound' partly offsetting the initial drop. The larger the increase in demand for coal, the larger the degree to which the rebounding emissions offset the initial environmental benefits of the efficiency gains. In some cases, the use of coal increases, and the energy efficiency gains 'backfire', leading to worse environmental outcomes than would have happened in the absence of technical progress.[3]

In the case of Colombia, a particularly fraught area in this respect is land-use for agricultural purposes and the associated deforestation pressures. As the drive to develop a sustainable bioeconomy in Colombia is likely to include the deployment to scale of higher-value-added crops and technologies, the productivity of agricultural land is bound to increase. Increasing the productivity of agricultural land provides incentives to find more land for use in agriculture to expand production and profits. This expansion may well end up putting more pressure on intact forested areas and threatening a loss of biodiversity and other ecosystem services.

Consider the diffusion of enhanced pasture techniques for cattle ranching as an example. Such an enhanced system has considerable productivity advantages relative to standard cattle ranching approaches. As the yield per unit of land increases, the producers can supply more meat to the market, at a lower cost. Provided that the demand is elastic, the market price decreases, and the innovators' market share increases as they can undercut traditional producers. The more elastic the demand curve, the smaller the price reduction and the larger the increase in profits experienced by the technology adopters. These producers, however, now face a greater incentive to bring more land into (enhanced) production as the opportunity cost of conservation has increased.

The risk of experiencing significant rebound or even backfire effects, therefore, hinges on the elasticity of demand for the product in question. The degree of connection between the domestic market and the international meat market is key in this respect: the better the producers' access to international markets, the more elastic the demand curve they face – the additional supply has at best a modest impact on the international price of meat, and the efficiency gains lead to large profits and significant incentives to expand production.

In countries producing internationally traded agricultural commodities, the domestic land expansion effect risk is therefore at its highest. The effect may be counteracted in other countries when their production is displaced by international competition and their deforestation pressure is reduced. Indeed, Villoria et al. (2019) show that for many commodities, and across several countries, a localized backfire coexists with a reduction in the area devoted to the production of the specified commodity at the global level.

Measures need to be taken to reduce rebound, either by reducing the attractiveness of deforestation/possibility of expansion or by making alternatives more appealing. In countries like Colombia which possess agricultural and conservation areas of high value, rebound effects leading to land expansion could be mitigated by land-use regulations restricting land conversion expansion into sensitive and high-value conservation areas. ▲

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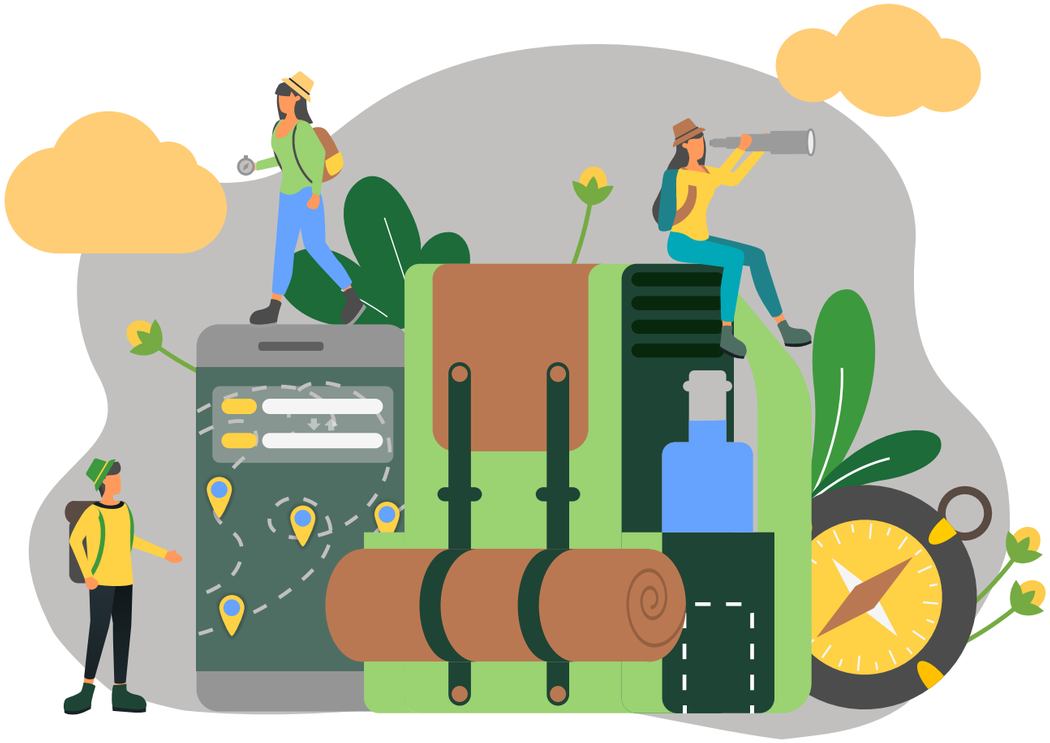
3 This extreme type of rebound effect is indeed sometimes referred to as the backfire effect (Saunders 1992).



4. Background information on bioeconomy initiatives

The early OECD (2009) report on bioeconomy supported a bio-technologic pathway in which global cooperation could enhance resource use through science and innovation. The Global Bioeconomy Summit (Communiqué, 2018) reports that a bioeconomy development path should seek to reduce dependence on fossil fuels and promote the production and use of knowledge on biological resources, processes and principles for the sustainable supply of goods and services in all sectors of the economy (bioenergy, agriculture and bio-inputs, food, fibres, health products, industrial bio-products, bioplastics, ecotourism). However, to globally achieve these objectives, multiple challenges exist and, in the latest OECD report (2019), we can find the complexities and barriers that need to be overcome. Primarily, an international legislative framework to protect intellectual and scientific discoveries should exist and a multi-sector/stakeholder engagement process should be established. Contrary, in smaller scale bioeconomy initiatives the coordination costs are reduced, and the stakeholders' engagement and support can be sought at the bioeconomy designing stage.

Sasson and Malpica (2018) have reviewed the bioeconomy development in Latin America and point out that Colombia was part of an EU project on bioeconomy which promotes the circular economy and green investments. Two complementary concepts, the circular economy (Pearce and Turner 1991) and the bioeconomy are therefore relevant to a sustainable development strategy in Colombia. Both concepts are anchored to the first and second laws of thermodynamics and focus on the need to manage the throughput of matter and energy through the economic system. Therefore, they emphasise the fundamental role the environment plays in supporting, but also limiting economic activity (rate and extent). Both constructs place carbon footprint reduction and increased resource use efficiency/ eco-efficiency high up in the policy priority agenda. The bioeconomy involves the production and use of biological resources. The use of terrestrial and marine renewable resources is given high priority, alongside the minimisation and utilisation of residual waste products. The outputs encompass value-added products such as food, feed, a diverse range of other bio-based products and bio-energy together with recreation/amenity and other cultural ecosystem services.

In 2018, the Colombian government produced an official definition of bioeconomy as an "economy that efficiently and sustainably manages biodiversity and biomass to generate new value-added products, processes and services based on knowledge and innovation" (Consejo Nacional de Política y Economía Social– CONPES 3934, 2018). The relevance of biodiversity and biomass is clear in the Colombian definition but Sasson and Malpica (2018) reflect that "relying on biodiversity is not synonymous with biodiversity conservation", which suggests the necessity to carefully consider the three pillars of sustainability and SDGs before supporting specific bioeconomy investments.

In the same year, the national government invited a group of 47 national and international experts of diverse disciplines to provide policy recommendations in eight topic areas that were deemed key for the sustainable technological, social and economic development of Colombia. One of these topics was Biotechnology, Bioeconomy and Environment. La Misión Internacional de Sabios (International gathering of experts in Spanish), conducted six regional workshops to identify the regional barriers, opportunities and policy recommendations for the development of a sustainable bioeconomy strategy in 2019. Leaders, academics, governmental institutions, associations, farmers and other key social actors were participants in these discussions. The key findings of these regional meetings are summarized in Box 1 and 2.

Other studies exist that have analysed trends, opportunities and limitations of bioeconomy development in Colombia, including Aramendis and Castaño (2019) who presented a brief description

Box 1 - Villavicencio workshop - 13th of May of 2019

Main opportunities for the Orinoquía are:

- Unique environmental conditions, rich biodiversity and cultural assets: the environmental conditions of the region, its rich biodiversity, and diverse ancestral knowledge enables the development, discovery and creation of high-value bioeconomy product and services.
- Increasing environmental awareness and actors interested in green business development: the peace treaty and its environmental component has been a driver of awareness and interest on the protection of the environment. International and national entities are increasingly financing green projects in the region.

Main barriers for bioeconomy projects are:

- Non-sustainable extractive based economy: the economy of the Orinoquía is mainly based on the exploitation of oil and natural gas, and the extension of cattle-ranching and agroindustry activities, this enters in conflict with environmental conservation goals.
- Unclear and weak environmental regulatory framework: lack of knowledge and confusion regarding current regulations and norms. In general, local authorities do not seem interested in implementing and creating regulations, nor enforcing and monitoring them: this motivates illicit and informal activities. Land titling procedures are also unclear.
- Policy making is strongly centralized: governmental decision making is not coherent with the local needs. Most public and research projects are done by foreign actors with poor knowledge of the territory. Indigenous and minority groups are poorly considered, this generates tensions among ethnic communities and other residents.
- No science culture: there is no scientific and research appropriation nor vocation in the local community. The infrastructure for R&D is minimal and there are very few high-education facilities. In addition, ancestral knowledge is poorly accounted in science, technology and innovation projects.
- Poor governmental management and weak institutions: there is no political appropriation or long-term institutional vision. In general, residents do not trust on governmental institutions. Finally, the region has encountered several threats: armed conflict, illicit crops development, lack of ecosystem and environmental knowledge.

La Misión Internacional de Sabios, in 2019, conducted six regional workshops to identify the regional barriers, opportunities and policy recommendations for the development of a sustainable bioeconomy strategy.

Box 2 - Pereira workshop - 24th of May of 2019

The main purpose of the workshop was to identify policy recommendations for the development of Bioeconomy opportunities. Main suggestions are:

- Finance: it is key to increase the sources of funding for science and research development. Parafiscal revenues are proposed to be used for this purpose. Finally, it is also important to create alliances between the public and private sector.
- Regulation: entrepreneurship aligned with the conservation of the environment must be encouraged, one strategy is to create added value on biodiversity. It is key to legalize and protect ancestral knowledge property rights and ensure its diffusion.
- Institutional: key to encourage cooperation among actors, and to create boards and working networks of multidisciplinary character.
- Human resources and education: acknowledgment of education as essential for bioeconomy development. Importance of encouraging political education focused on vocation and science.
- Infrastructure: a diagnosis of current infrastructure capacity of institutions and universities is needed to generate strategic alliances.
- Science culture: need of creating a science culture; through basic education, incentivising scientific vocation programs, and training school professors.

and analysis of the experience of some Latin-American countries in the context of a national bioeconomy growth strategy. For the Colombian case, the authors selected 10 bioeconomy companies within the sectors of bioenergy, biotechnology, eco-intensification, and pharmaceutical and cosmetics to understand what factors were hindering and facilitating their development. They found that, in some cases, the current normative framework is seen as a barrier for bioeconomy business progress due to regulatory gaps, slow and inefficient bureaucratic process and multiple interpretations of the regulations. In addition, there was also some consensus that stronger social and environmental sustainability standards need to be implemented. The authors also found that 80% of analysed companies are private businesses with ownership of natural resources. Finally, the analysis pointed out that intellectual property practices need to be encouraged, as many businesses are just starting to protect their innovations, and this represents a limiting factor.

In addition, in November 2019 Colombia hosted a workshop on bioeconomy and Canales and Gonzales (2020) summarised the results of this meeting. Representatives from the government and leading stakeholder groups participated in the meeting and the relevance of wider sustainability considerations of bio economic initiatives in Colombia were formally recognized.

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Felipe Villegas, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt

From the meeting it emerged that current Colombian initiatives are promoting bio-products such as cosmetics and cleaning products, chemicals, pharmaceuticals, health care, agriculture and livestock, and food and beverages. Hopes exist for future investments in biotechnology for mining and biogas/energy from food waste.

Canales and Gonzales (2020) acknowledge that bioeconomic investments should reflect the local diversity and be inclusive and fair for the society and economy. They concluded that the main barriers in Colombia inhibiting a programme of sustainable bioeconomy investments are:

- Land ownership.
- Funding.
- Trade-off between employment and innovation.
- Standard of sustainability.
- Intellectual and property rights.

The shared conclusion of this meeting was that to fully develop the bioeconomy potential in Colombia it was necessary to invest in R&D and create public-private alliances with strong business support and involvement, as well as better coordination of different policies and actors. Therefore, the success of the bioeconomy is linked to the existence of, and further development of, a network of stakeholders.

Hernández and Schanz (2019) conducted a detailed analysis of key actors for bioeconomy activities in Colombia and following the principle of network analysis they produced the graph in Figure 3. Red dots represent the government, green the private sector, grey and blue the research community and academia, yellow the international players and orange the NGOs. The predominant role of the government is clear as the red dots are bigger and central to the network. Many other players are included, and the authors reported the 20 most influential actors (Table 1). ▲

Therefore, the success of the bioeconomy is linked to the existence of, and further development of, a network of stakeholders.

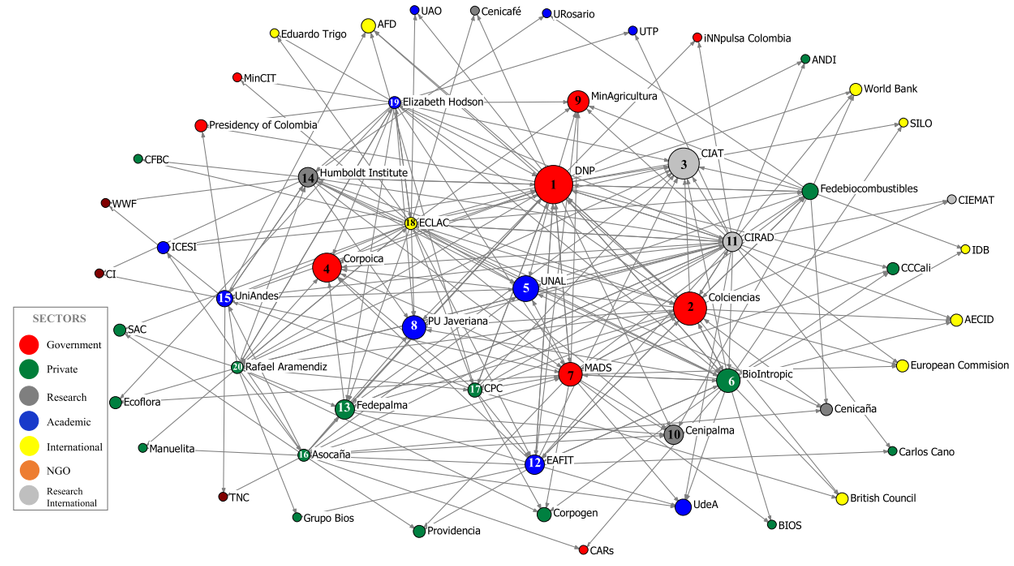

Figure 3
Colombian bioeconomic actors (Hernández & Schanz 2019)

Description of actor
National planning department (government)
Science, technology and innovation administrative department (government)
International agriculture institution (research)
Agriculture research institution (government)
National public university (academic)
Biotechnology business center (private)
Ministry of environment (government)
Ministry of agriculture (government)
Sugar cane research corporation (private)
Cooperation agency (international)
Oil palm growers federation (private)
Biodiversity institute (research)
Private university (academic)
Sugar cane growers association (private)
Competitiveness council (private)
LAC Economic commission (international)
Individual expert (academic)
Individual expert (private)

Table 1
The most influential actors for bioeconomy initiatives

Note: Science, technology and innovation administrative department (Colciencias) is now the Ministry of Science, Technology and Innovation (Minciencias).

5. Bioeconomy selection strategy for the four regions

Our research focuses on four Colombian regions: Antioquia, Valle del Cauca, Coffee Zone and Orinoquía, and follows a bioeconomy project selection framework (Figure 4). The asset check on economic, social and environmental conditions is conducted on all Colombian departments and sets the characteristics of the regions which, in turn, determine the development of bioeconomy opportunities.

The stakeholders analysis aims to identify the key players in the regions and to gather their preferences and opinions on current and future bioeconomy initiatives. This analysis is conducted in two steps: desk collection of contact details and distribution of an online survey. Finally, regional workshops conclude the process of selecting and designing bioeconomy projects for the regions.

5.1 Asset check with cluster analysis

The first step involves a macro-analysis of the economic, social and natural assets through a multidimensional analysis. The

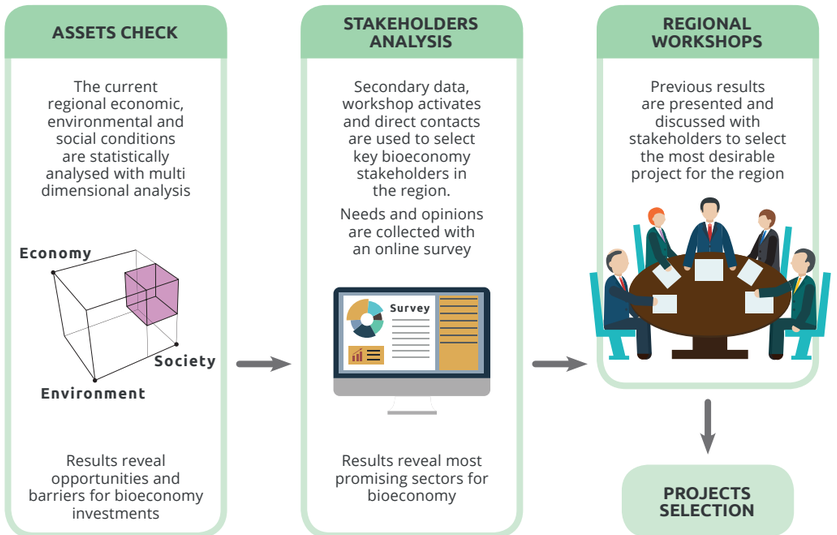

Figure 4
Bioeconomy projects selection process

assets check analysis aims to provide a baseline measurement to determine the opportunities for bioeconomy projects and to set the benchmark of success of future initiatives.

The multi-dimensional analysis for the assets check is performed through a clustering approach. Cluster analysis is a well-known classification technique (Bartholomew et al 2008) and is extensively used in many fields of application. It aims to assess if a set of objects or indicators can be meaningfully summarized in terms of a number of groups (or clusters), with objects or indicators within each group resembling each other based on some specified characteristics as assessed through some quantitative measures of closeness (Everitt et al 2011). In other words, referring to our application, the cluster analysis allows us to group Colombian departments based on observed similarities in economic, social and environmental conditions. We employ a partitioning cluster analysis, which is an approach breaking the observations in k distinct non-overlapping clusters such that the observations within the same cluster are as similar as possible. The partitioning method used in this application is the PAM algorithm (Partitioning Around Medoids, Kaufman and Rousseeuw, 1990), which is a k-medoid type algorithm that provides clusters built around the most representative observation (one per cluster). For this reason, PAM is less sensitive to outliers and noise in data than other partitioning methods.

The development and application of the PAM clusterization followed sequential steps starting with the collection of all variables representing the current conditions of the regions and ending with the graphical mapping of the resulting clusters. Figure 5 summarises the main steps of the process followed.

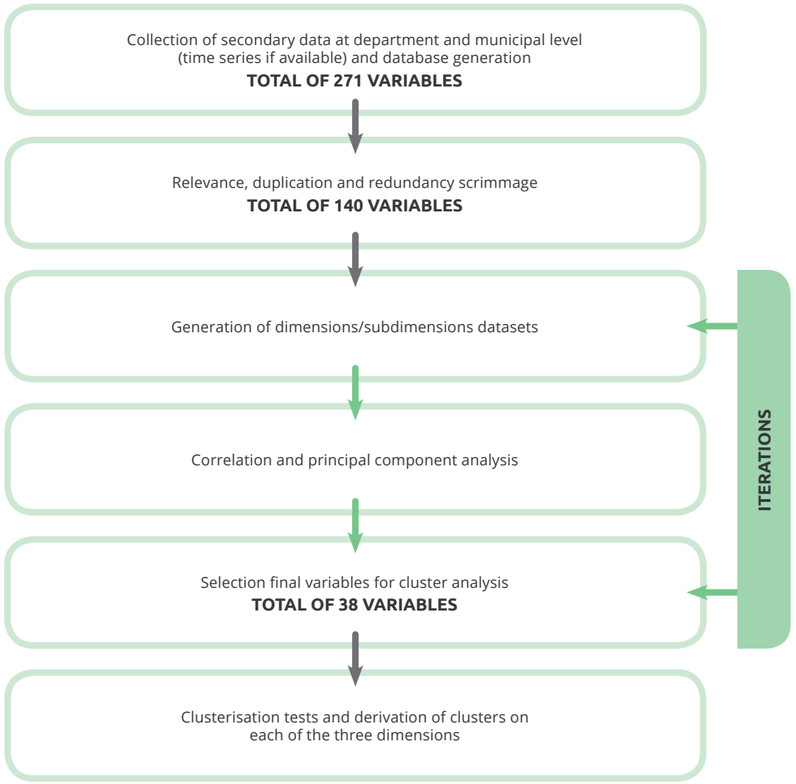

Figure 5
Workflow process of the cluster analysis application

The dataset for the cluster analysis was initially developed by collecting all the secondary data of interest from publicly available sources. Variables' collection was guided by the need to describe the three pillars of sustainability and gather information to examine the economic, social, and environmental baseline endowment of Colombian departments. A total of 271 department level variables were collated in a single dataset and were subsequently reduced to 140 variables after a first selection based on conceptual relevance to describe conditions for bioeconomy development and avoid duplications. The variables could then be further grouped based on the sustainability dimensions and subdimensions they describe (Table 2).

Table 2
Dimensions and subdimensions of sustainability for the assets check

Economic	Social	Environmental
Public finances	Basic needs/Inequality	Deforestation/Env impacts
GDP	Education	GHG emissions
Agri-food intensity	Access to IT and credit	Protected areas
Access to markets	Local knowledge	Key ecosystems
	Crime rates	

Principal component and correlation analyses were performed on each of the subdimension separately, to maximise the information used to describe the subdimensions while limiting the number of variables to use. This was an iterative process: correlations and principal components underlying the subdimension variables were performed until a robust solution was found[4]. The data reduction process selected 38 fundamental variables to capture the sustainability subdimensions (Table 3).

The cluster analysis was performed separately on the variables describing the economic, social and environmental dimensions of sustainability. Check of clustering tendency and selection of the optimal number of clusters to impose on the data structure are relevant preliminary steps to the actual analysis. We used different approaches to examine the clustery tendency (Hopkins statistics and Visual Assessment of Cluster Tendency) and the optimal number of clusters (Elbow method) differences in clustering effectiveness when adding or removing one cluster, and consistency in the number of clusters used for each dimension. A solution with five department clusters was chosen. Details of the preliminary clustering tendency and optimal cluster selection are provided in Appendix I.

In the following subsections, results of the cluster analysis for each sustainability dimension are mapped and the main characteristics of the clusters are summarised. Detailed average values of the variables used in the cluster analysis are reported in Appendix II.

Economic cluster analysis

The economic variables generally cluster the Colombian departments following their specialisation. A central area, located in the Andean and Caribbean region, is more densely populated and has higher connectivity and access to markets, is less reliant on public transfers and debt, and has a well-developed services sector. A more peripheral group of departments (Amazon and Orinoquía regions, Chocó) are more reliant on public finances, less connected and populated, and with a GDP driven by agriculture and mining. The departments in the Coffee Zone (Caldas, Risaralda, Quindío) have peculiar characteristics related to the highly developed agribusiness sector. Figure 6 shows the five economic clusters identified and the main characteristics of the clusters are reported in Table 4.

Economic Cluster 1: the *service-led highly developed cluster* includes the four departments in the north Andean region and the Atlántico department. Departments in this cluster are characterized by the lowest levels of fiscal transfers from the central government (~5,660 COP$/capita) and public debt (~790 COP$/capita). The main GDP contributions are related to the service sector (~46,290 COP$/capita), which is particularly relevant for the coastal department Atlántico, and the industrial and construction segment (~36,820 COP$/capita).

4 For each subdimension, a correlation analysis was first performed on the complete set of normalized variables and strong to very strong pairwise correlations (i.e., higher than 0.7-0.8) were flagged for possible redundancy of information provided. The principal component analysis (PCA) was then performed on the same set of complete variables. A first PCA was aimed at identifying the optimal number of components (i.e., those with eigenvalue higher than 1) and a second PCA constraining the number of components was used to examine factor loadings, with variables loadings lower than 0.3-0.5 flagged as less informative. The process was iteratively performed until variables in each subdimension showed moderate correlation and factor loadings greater than 0.3-0.5 on a total of one to three components, depending on the number of variables.

Table 3
Final list of variables for the assets check

	Subdimension	Variable	Source	Unit
ECONOMIC (15)	Public finances	Fiscal transfers to local government	MinHacienda	COP$/capita
		Departmental debt	CGR, DNP, SF	COP$/capita
	GDP	GDP agriculture	DANE	COP$/capita
		GDP mining	DANE	COP$/capita
		GDP industry, constructions, transport	DANE	COP$/capita
		GDP public services	DANE	COP$/capita
		GDP third sector	DANE	COP$/capita
	Agri-food intensity	Area pastures	DANE	% total area
		Area agrobusiness (coffee, cacao, sugar, etc.)	DANE	% total area
		Area tubercles, vegetables, and fruit	DANE	% total area
		Area cereal	DANE	% total area
		Area flowers, medicinal plants, forest plants	DANE	% total area
	Access to markets	Paved highway	IGAC	mt/km^2
		River density	IGAC	% total area
		Urban population	IGAC	pop/km^2
SOCIAL (11)	Poverty/Inequality	Agricultural productive units with own land tenure	DANE	% total units
		Land Gini	IGAC	0 to 1
		Multidimensional poverty index	DANE	% households
	Innovation	Higher education	DANE	% total population
		Agricultural units with machineries	DANE	% total units
		Agricultural units with technical assistance	DANE	% total units
		Agricultural units with access to credit	DANE	% total units
		Internet coverage	DANE	% total households
	Local knowledge	Indigenous & Afro-Colombian communities	ANT	% total area
	Crime rates	Coca crops area	UNODC	hectares
		Crime rates (thefts + homicides)	DNP	n/100000 hab
ENVIRONMENTAL (12)	Environmental impacts	Deforestation rates	Hansen et al, 2013	%
		Net GHG emission	IDEAM	Mt CO_2eq
		Human Spatial Footprint Index	IAvH	% total area
	Characteristics	Altitude	NASA & NGA	meters
		Water surplus	IDEAM	% total area
	Protected areas & Key ecosystems	Protected areas	PNN	% total area
		Birdwatching sites	IAvH	% total area
		Pristine forest	UPRA, MADS	% total area
		Dry tropical forest	IAvH	% total area
		Wetlands	IAvH	% total area
		Páramo	IAvH	% total area
		Mangroves	IAvH	% total area

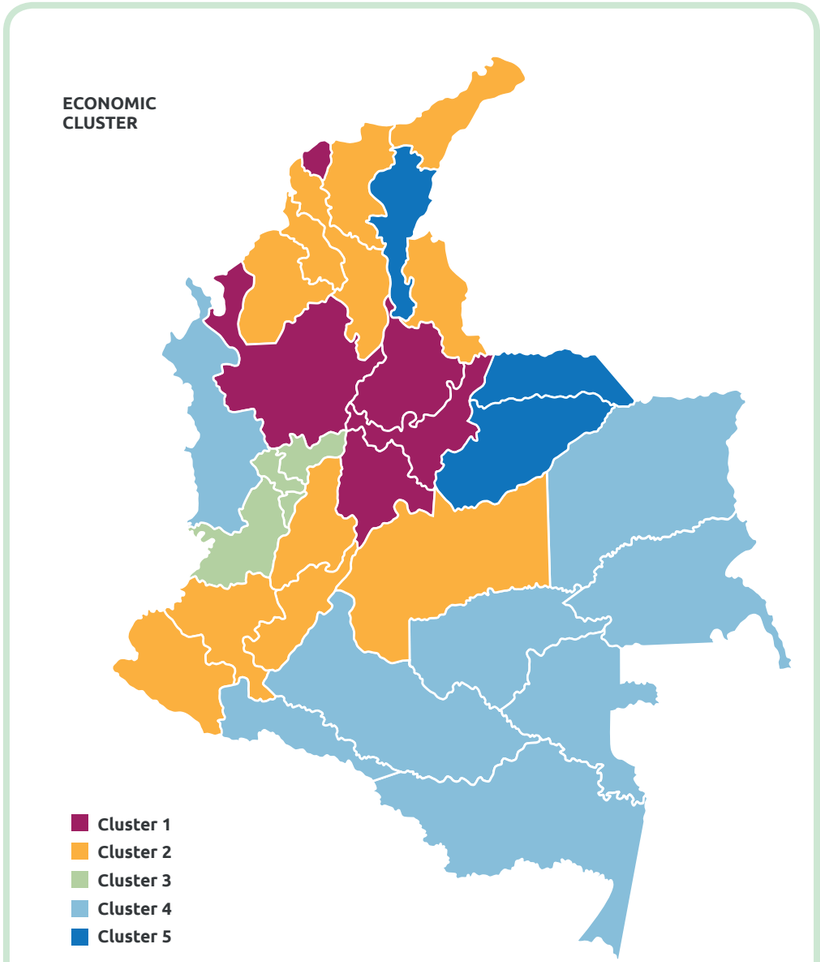

Figure 6
The five economic clusters of Colombian departments

Services-led highly developed cluster **(Cluster 1)**	Low dependence on fiscal transfers and public debt. High reliance on the services sector. Densely populated and connected urban agglomerates.
Balanced development cluster **(Cluster 2)**	More balanced economic development with some local peculiarities regarding pastures and agricultural products. Medium-low connectivity and dependence on public transfers and debt.
Coffee Triangle cluster **(Cluster 3)**	Coffee Axis. High relevance of agribusiness sectors (coffee, sugar cane, fruit) and services. High access to markets with high-density highways.
Rural development cluster **(Cluster 4)**	High dependence on fiscal transfers, public debt and social services. Generally low agribusiness and pasture area with some local exceptions. Low urban population density, low highway connectivity, but high fluvial density.
Primary sector-led cluster **(Cluster 5)**	High importance of mining and agriculture, in particular related to pastures and cattle ranching. High levels of fiscal transfers and public debts. Low connectivity and urban population density.

Table 4
Summary of the economic clusters

Even considering the substantial percentage of land dedicated to pastures (~33%), the contribution of agricultural activities to the GDP is the lowest compared to the other economic clusters (~6,040 COP$/capita). Departments in this cluster are highly populated (~18,410 pop/km^2 in cities) in particular in Antioquia and Cundinamarca. With ~260 metres of paved highway per km^2, the cluster benefits of one of the highest connectivity levels compared to the other clusters identified.

Economic Cluster 2: the *balanced development cluster* includes most of the departments in the Caribbean region, four departments in the south Andean region and Meta located in the Orinoquía region. This cluster is characterised by low levels of fiscal transfers (~14,470 COP$/capita) and public debt (~915 COP$/capita). Like departments in cluster 1, the GDP is mainly based on services (~64,870 COP$/capita) and the industrial and construction sector (~35,370 COP$/capita), but in contrast to cluster 1, also agriculture (~17,510 COP$/capita), especially in Huila, Meta, Tolima and Santander, and mining (~32,900 COP$/capita), especially in Huila, are important. This cluster is characterized by an average coverage of pastures of around 23% of the total area (as large as 43% in Meta, 40% in Cordoba, and 34% in Sucre), an average area destined to cereal of around 3% (more than in any other economic cluster), an average area destined to tubercle, vegetables and fruit equal to around 5.8%, and an average area farmed with agribusiness products of around 4.5% (with particular relevance in Huila, Cauca and Tolima). Access to markets is on the lower end compared to other economic clusters, with ~95 meters of paved highway per km^2 and urban population density equal to ~1,720 pop/ km^2).

Economic Cluster 3: the *Coffee Triangle cluster* includes most of the departments located in the Coffee Axis, namely Caldas, Quindío, Risaralda and Valle del Cauca. Whilst services are a relevant part of the GDP (private services ~177,980 COP$/capita, public services ~13,730 COP$/capita) especially in Quindío, it is not surprising that the agricultural sector makes one of the highest contributions to GDP compared with the other economic clusters (~37,780 COP$/capita). This is driven by the large area cultivated with agribusiness products (16.4%) and with tubercles, vegetables, and fruit (17.6%). Especially important are coffee, fruit, and tubercles in Caldas, Quindío, Risaralda, and sugar cane and fruit in Valle del Cauca. Departments in this cluster also have the highest density of paved highway (284 m/km^2).

Economic Cluster 4: all the departments in the Amazon region, Vichada (in the Orinoquía) and Chocó (in the Pacific) are grouped in the *rural development cluster.* This cluster receives the highest fiscal transfers from the central government (~230,800 COP$/capita) and has one of the highest levels of public debt (~2,830 COP$/capita). Its GDP is overall highly reliant on services (~389,360 COP$/capita), in particular social services. Transport services are relevant in Guaviare (~159,300 COP$/capita) and Vaupés (~120,960 COP$/capita). Whilst the percentage of area destined to agribusiness is generally in line with other clusters, in Amazonas coffee (8.2%), palm oil (4.4%) and sugar cane (5.2%) assume an important role. Similarly, even if the average percentage of pasture area within the cluster is 9.4%, in Vichada pastures cover 37.1% of the department area. Departments in this cluster have the lowest density of paved highways (7 mt/km^2), the lowest urban population density (75 pop/km^2), but the highest fluvial density with rivers covering on average 16% of the total department area.

Economic Cluster 5: the three departments of Cesar, Arauca and Casanare are clustered in the *primary sector-led cluster.* The GDP in this cluster is reliant on several sectors, in particular mining (~381,784 COP$/capita, the highest amount between the clusters) especially in the two departments of the Orinoquía region Arauca and Casanare, and agriculture (~140,500 COP$/capita, the highest compared with other clusters) particularly with relation to pastures that cover 64% of the land area in Arauca, 62% in Casanare and 42% in Cesar. These departments have the second highest level of fiscal transfers (~80,900 COP$/capita) and the highest level of public debt (~4,260 COP$/capita), while showing low levels of connectivity (65 m/km^2 of paved highways) and population density (urban population is ~339 pop/km^2).

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Francisco Nieto Montaño, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt

Social cluster analysis

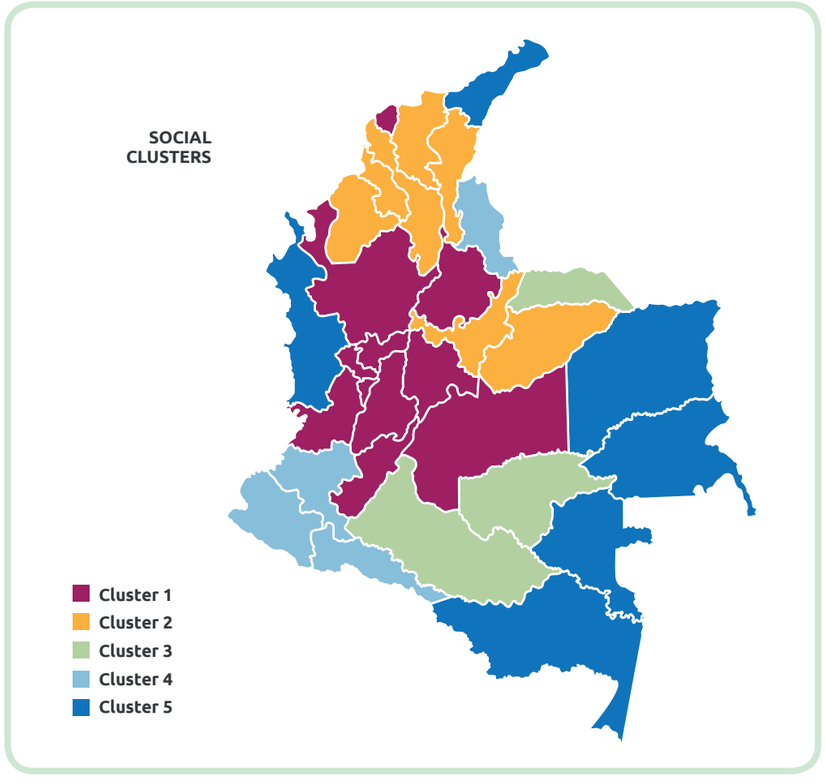
The analysis based on social variables differentiates Colombian departments in a core central area of the country with high levels of education and innovation potential and low multidimensional poverty, and more peripheral clusters with increasingly higher multidimensional poverty and lower innovation diffusion. Characteristics of some clusters are related to the high levels of fixed production assets in part of the Orinoquía and Amazon regions, and the relevant presence of local communities in the Amazon region and Chocó. Figure 7 shows the five social clusters identified and Table 5 summarises the main characteristics.

Social Cluster 1: the *Colombian representative cluster* includes most of the departments in the north and centre Andean region, Atlántico (in the Caribbean region) and Meta (in the Orinoquía region). Departments grouped in this cluster have the lowest level of multidimensional poverty (16.1% of households, especially low in Cundinamarca, Risaralda, and Santander) and a low percentage of productive units with own tenure (46.8% has individual ownership). This cluster also shows a high concentration of land ownership (0.8 land Gini) especially in Meta, Valle del Cauca and Huila. In addition, the cluster shows the highest levels of innovation diffusion with 19.7% of the population holding a higher education level (in particular Valle del Cauca, Santander, Atlántico and Antioquia), 43.1% of households connected to the internet (with higher diffusion in Valle del Cauca, Risaralda and Antioquia), and 25.7% of productive units benefiting of technical assistance (with levels as high as 43% in Risaralda and 39% in Caldas and Huila). Access to credit is also generally higher than in the other clusters (12% of all productive units). Departments in this cluster, especially Meta, Quindío, Risaralda, and Tolima, have the highest crime rates with an average of 457 crimes/100,000 people.

Table 5
Summary of the social clusters

Colombian representative cluster (Cluster 1)	Lowest multidimensional poverty, low proportion of productive with own tenure, but high land concentration. Highest innovation diffusion and potential. Highest crime rates.
Innovation potential cluster (Cluster 2)	Medium-high multidimensional poverty and resource concentration. Considerable levels of highly educated residents and internet diffusion, but lowest access to credit and technical assistance.
Rural technology cluster (Cluster 3)	Highest levels of fixed capital and machineries, but generally low innovation diffusion and potential. Low land inequality, but high multidimensional poverty.
Social transition cluster (Cluster 4)	Medium-high levels of multidimensional poverty and concentration of productive assets. Low innovation diffusion and potential. Relevant presence of local communities.
Ancestral knowledge potential cluster (Cluster 5)	Highest diffusion of local communities. Highest levels of multidimensional poverty and lowest levels of innovation diffusion and potential.

Figure 7
The five social clusters of Colombian departments



Social Cluster 2: most of the departments in the Caribbean region, Boyacá (in the Andean region) and Casanare (in the Orinoquía region) are grouped in the *innovation potential cluster.* Departments in this cluster are characterised by a high percentage of residents with a higher education level (15.8% on average, higher in Boyacá and Bolívar) and a medium-high percentage of households with an internet connection (23.2% on average, higher in Bolívar, Magdalena and Casanare). However, multidimensional poverty and productive assets inequality are also high, with the former being a particularly relevant issue in Sucre, Magdalena and Córdoba (average percentage of households is 30.9% within the cluster) and the latter in Sucre, Bolívar, Boyacá, and Casanare (within cluster average land Gini is 0.8). Finally, departments in this cluster also have the lowest access to technical assistance (9.2% of productive units) and to credit (8.7% of productive units).

Social Cluster 3: three departments are grouped in the *rural technology cluster,* Arauca in the Orinoquía region, Caquetá and Guaviare in the Amazon region. These departments are associated with the highest level of fixed capital hold by productive units, with 55.2% of them using specialist machineries. The concentration of land ownership is lower than in other clusters (land Gini is equal

to 0.6) whilst own tenure of productive units is the highest (61.8%). In addition, multidimensional poverty is the second highest (31.3% of households) among the social clusters. Departments within this cluster exhibit mid-low levels of innovation potential and diffusion compared to other clusters, with an average percentage of residents holding a higher education level equal to 12%, internet access in 13.9% of households, and access to technical assistance and credit respectively for 11.1% and 10% of productive units.

Social Cluster 4: the *social transition cluster* includes departments located in the southern (Cauca, Nariño, and Putumayo) and northern (Norte de Santander) margins of the Andean region. These departments are characterised by medium-high levels of multidimensional poverty and concentration of productive assets, especially in Cauca and Nariño, with a cluster average of 29.7% households in multidimensional poverty circumstances and a land Gini equal to 0.8. Departments in this cluster show innovation levels higher than social cluster 3, but substantially lower than social clusters 1 and 2. The presence of local communities is the second highest among the social clusters identified at an average 0.3% of the total area. Particularly relevant are Afro-Colombian communities in Cauca and Nariño and Indigenous communities in Putumayo.

Social Cluster 5: the *ancestral knowledge potential cluster* includes most of the departments in the Amazon region, Chocó in the Pacific region and La Guajira in the Caribbean region. This cluster is characterised by a relevant presence of local communities (0.7% of the total area), in particular Afro-Colombian communities in Chocó and indigenous communities in the Amazonas and in La Guajira. Whilst there is a lower concentration of land (0.6 land Gini), multidimensional poverty is the highest affecting, on average, 51.8% of households, reaching 65% in Guaviare and 59.4% in Vaupés. In addition, this cluster is characterised by the lowest levels of innovation potential and diffusion, with only 7.9% of households with internet access, 8.8% and 2.3% of productive units respectively with access to technical assistance and credit, and 9.2% of residents holding higher education levels.

Environmental cluster analysis

The analysis based on environmental variables groups Colombian departments resembling the country's natural regions, particularly the Andean, Amazon and the Caribbean regions. Colombia is a megadiverse country, with several different ecosystems and ecological particularities. Therefore, even if clusterisation effectively differentiates between environmental features, some outliers are likely. For example, Arauca and Casanare in the Orinoquía region are characterised by an exceptionally high extension of wetlands but the level of human impacts makes them similar to Caquetá and Antioquia. The high presence of forest areas in Chocó, together with low human impacts, makes it more similar to the Amazon region

Floodplain biodiversity cluster (Cluster 1)	Wetlands are a highly relevant ecosystem. High GHG emission levels, deforestation and human footprint. Medium diffusion of protected areas and birdwatching sites.
Highest spatial human footprint cluster (Cluster 2)	Wetlands and dry tropical forests are highly relevant ecosystems. Highest human footprint and deforestation rate. Protected areas and birdwatching sites are in specific departments.
Páramo, parks and biodiversity cluster (Cluster 3)	Páramo is a highly relevant ecosystem. This cluster has a localised presence of dry tropical forests. High human footprint, but highest levels of protected areas and birdwatching sites.
Pristine forests cluster (Cluster 4)	Forest areas are a highly relevant ecosystem. Lowest human footprint and GHG net emissions. Noticeable diffusion of protected areas but low presence of birdwatching sites.
Nariño diversity cluster (Cluster 5)	Nariño can be considered as an outlier of the Andean region, with the presence of diverse ecosystems, low human footprint and lowest deforestation. Low diffusion of protected areas and birdwatching sites.

Table 6
Summary of the environmental clusters

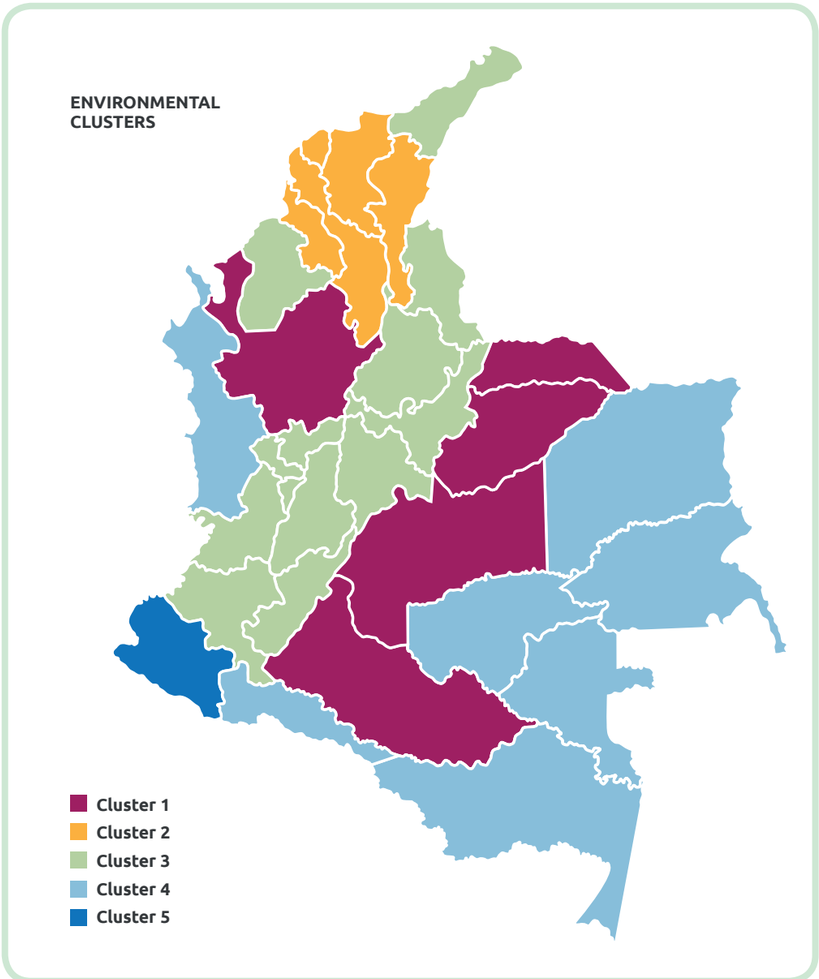


Figure 8
The five environmental clusters of Colombian departments

than the Pacific. The same line of reasoning is applied to other departments like La Guajira and Nariño. Figure 8 shows the five social clusters identified and Table 6 summarises the main characteristics.

Environmental Cluster 1: the *floodplain biodiversity cluster* includes most of the departments of the Orinoquía region (Arauca, Casanare and Meta), Caquetá and Antioquia. The five departments are characterised by high water surplus and the presence of large wetland areas (on average 36.5% of total area), especially in Arauca (67.8%) and Casanare (74.1%) which form an ecological sub-cluster concerning this ecosystem. This cluster exhibits the highest level of GHG net emissions (~12 Mt CO_2eq), with a deforestation rate between 2014 and 2019 equal to 4.6% (second highest between the clusters identified) and a high human spatial footprint in 26.6% of the department area. GHG net emissions are particularly high in Caquetá (~19 Mt CO_2eq) and Meta (~17 Mt CO_2eq), whilst deforestation rate is the highest in Arauca (6.8%) and human footprint in Antioquia (39.3%). Finally, the presence of protected areas and bird watching sites is widespread, particularly in Caquetá.

Environmental Cluster 2: most of the departments in the Caribbean region form the *Highest spatial human footprint cluster.* Departments in this group are characterised by wetlands (cluster average is 26.8% of total area) and the largest extension of tropical dry forests (cluster average is 3.9% of total area). Human impact on ecosystems is highlighted by the highest spatial footprint (average of 54.1% of total area, reaching 73.4% in the Atlántico department), the highest deforestation rate (7.6% on average, reaching 8.4% in Magdalena and 9.4% in Atlántico), and lowest water surplus (27.6% of the area). There are within- cluster differences with respect to protected areas that are very limited in Atlántico and Bolívar and more abundant in Magdalena, and birdwatching sites that are more frequently found in Bolívar than in the other departments.

Environmental Cluster 3: the Andean region, Córdoba and La Guajira (both in the Caribbean region) are grouped in the *Páramo, parks and biodiversity cluster.* Departments in this cluster are associated with a substantial human spatial footprint (on average 43.7% of total area, up to 55.4% in Cundinamarca, 53.6% in Quindío and 52% in Caldas) but mid-level deforestation rates (cluster average is equal to 2.6% between 2014-2019). The cluster is characterised by the highest presence of protected areas (on average 17.9% of total area) especially in Valle del Cauca, Quindío, Risaralda, and Santander, and of birdwatching sites (on average 11.1% of total area) particularly in La Guajira, Córdoba, Santander, and Risaralda. Departments in this cluster that are located in the Andean region are characterised by large Páramo areas, for example, Boyacá with 24.3% of land coverage, Tolima with 14.3%, Cundinamarca with 10.9% and Quindío with 10.1%. La Guajira is an outlier in terms of the high-importance ecosystems present, with a larger extent of forests (56% of total area) and dry tropical forests (3.1% of total area).

Environmental Cluster 4: the pristine forest cluster groups most of the Amazonian departments and Chocó (Pacific region). These departments are associated with the lowest human spatial footprint (cluster average is 7.1% of total area) and the lowest GHG net emissions (cluster average of (~3 Mt CO_2eq). With the highest level of water surplus between the identified environmental clusters, departments within cluster 4 are mostly characterised by large forest areas (cluster average 63.8% of total area), especially Chocó (84%), Vaupés (77%), and Amazonas (73%), and by wetlands especially in Vichada (38.7% of the total area). Whilst protected areas are common (cluster average is 16.4% of total area, reaching 35% in Guaviare and 21% in Amazonas), birdwatching sites are much less frequent than in the other clusters.

Environmental Cluster 5: the south-western department of *Nariño forms a cluster* by itself (the Nariño diversity cluster) and can be viewed as an outlier of the Andean region cluster. The department is characterised by some of the highest mountains in the country and diverse geography with large areas of forests (47.3% of the total area), wetlands (21.2%), páramos (6.7%) and mangroves (3.7%). The deforestation rate is the lowest compared to the other environmental clusters defined (1.1% in 2017-2019) and the human footprint is lower than most of the other departments (23.5% of the total area). However, few protected and birdwatching sites are located in the department, which is 6.1% and 4.6% of the total area respectively.

Photo by: *Federico Pardo, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt*

Socio-economic characterization of the four regions and temporal dynamics

The cluster results offer a national view of the opportunities for bioeconomy considering the wealth of economic, social and environmental assets. However, this analysis provides a screenshot of the current conditions. To analyse trends and tendencies, in this section we focus on the historical economic performance of the four regions targeted.

Table 7 portrays the key socioeconomic characteristics of the four regions. These regions have, overall, better macroeconomic outputs than the Colombian average. In 2018, only the Coffee Zone presented a GDP per capita lower than the national average. The Orinoquía region presents the highest GDP per capita among the studied regions, although it has the highest levels of Unsatisfied Basic Needs (NBI) and the lowest Human Development Index (HDI). This is explained by the high share of Mining and Quarrying in its economy, which is known to be associated with low levels of regional input-output linkages (Martinez and Aguilar 2013) and with aggravation of social inequalities in developing countries with weak institutions (Bird 2016). Antioquia, Valle del Cauca and Coffee Zone present lower levels of poverty (measured with the NBI index) and higher levels of multidimensional development (measured with the HDI index) compared to the national aggregate.

Figures 9 and 10 present the sectorial GDP composition of the regions: a) Antioquia, b) Valle del Cauca, c) Orinoquia d) Coffee region. The economy of the Orinoquía region is highly dependent on Mining and Quarrying activities. In 2018, 45% of the Orinoquía's total GDP was associated with the exploitation of crude oil and natural gas. During the 2008-2011 period, the sector experienced an annual average growth of GDP equivalent to 19%, which corresponded to 68% of the total GDP annual growth of the Orinoquía. After 2011, the economic output of this sector has slightly decreased, triggering a contraction in the economy of the region. The sector Commerce, Transport, Hotels and Restaurants also adds important value to the economy of the Orinoquía (13%

Table 7
Socio-economic characteristics of the four regions

Name of Region	Departments	Area (km²)	Population 2018	Rural population 2018	HDI 2018	NBI[B] 2018	NBI[B] rural 2018	GDP per capita 2018 (COP) [E]
Antioquia	Antioquia	62,804.7	6,407,580	22.4%	0.766	10.7%	26.8%	19,523,508
Valle del Cauca	Valle del Cauca	20,665.5	4,475,886	14.9%	0.785	6.2%	11.8%	18,779,687
Coffee Zone	Quindío, Caldas, Risaralda	12,915.6	2,481,560	21.5%	0.767[C]	8.1%[C]	16.0%[D]	13,603,912
Orinoquía	Meta, Arauca, Casanare, Vichada	253,836.2	1,830,208	29.6%	0.757[C]	19.8%[C]	41.0%[D]	26,069,141
Colombia	All	1,140,970	48,258,972	24.0%	0.761	14.3%	30.5%	17,689,199

Notes: A All data, except the HDI, was obtained from the National Department of Statistics (DANE). The HDI was obtained from United Nations Development Programme (UNDP); B NBI stands for Unsatisfied Basic Needs index; C Calculated as the departmental average weighted by total population; D Calculated as the departmental average weighted by total rural population; E Constant prices of 2015.

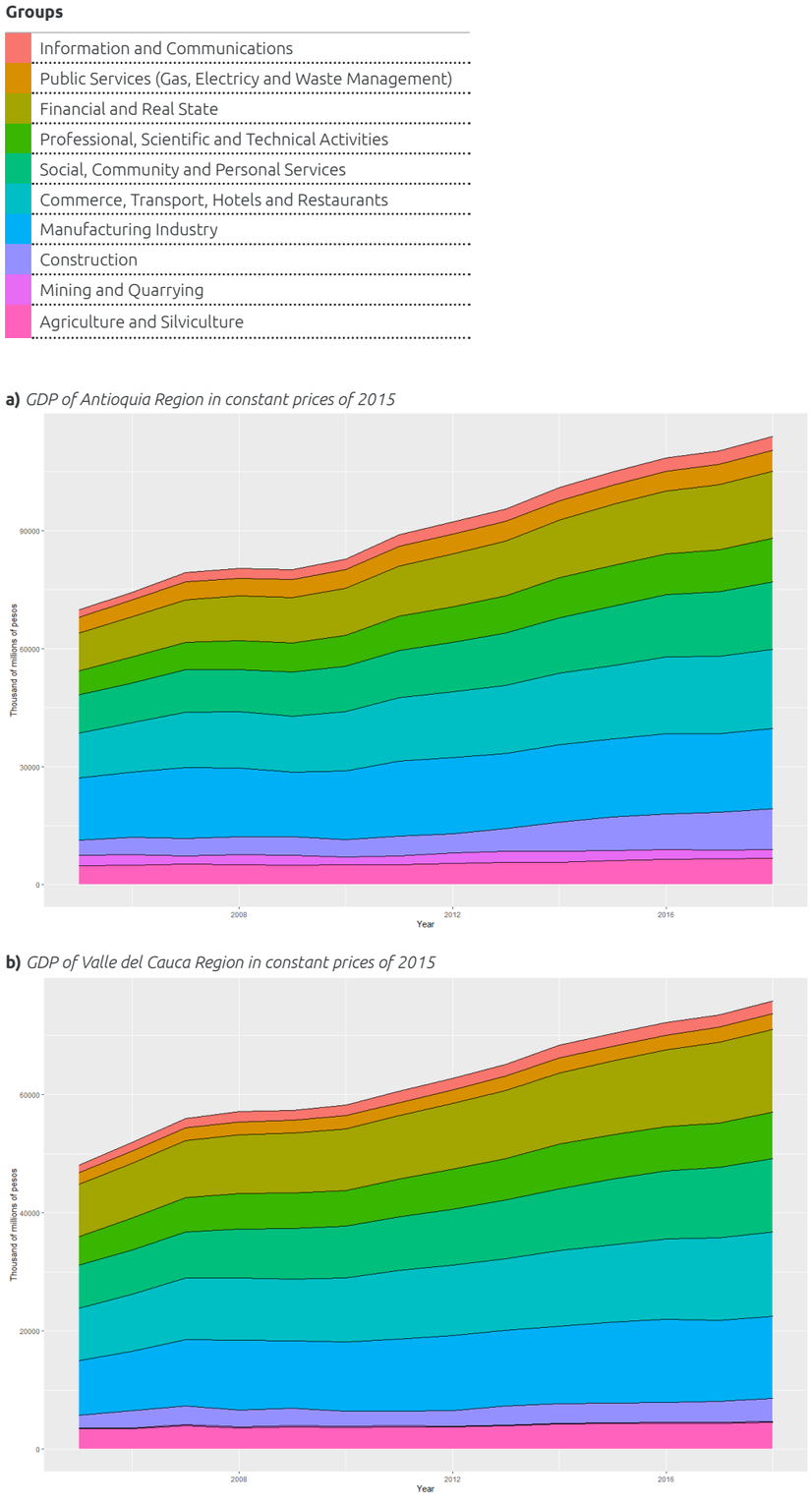
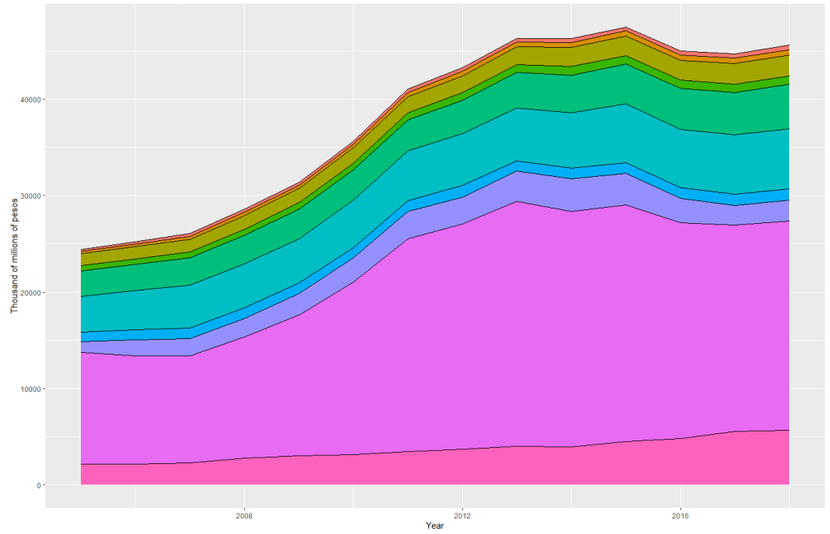


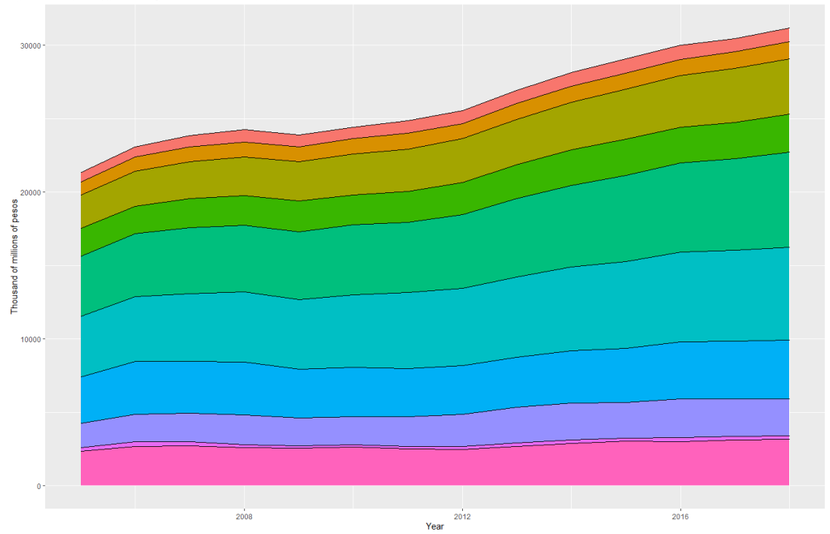
Figure 9
Sectorial composition of the GDP in 4 regions: a) Antioquia, b) Valle del Cauca, c) Orinoquia d) Coffee region. (Source: own elaboration on information from DANE, 2018)

Figure 9
Sectorial composition of the GDP in 4 regions: a) Antioquia, b) Valle del Cauca, c) Orinoquia d) Coffee region. (Source: own elaboration on information from DANE, 2018)

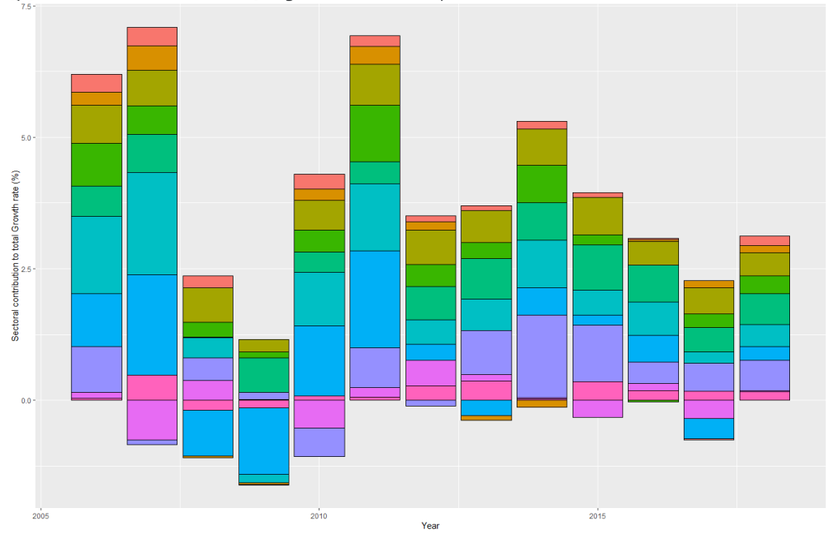
c) *GDP of Orinoquia Region in constant prices of 2015*



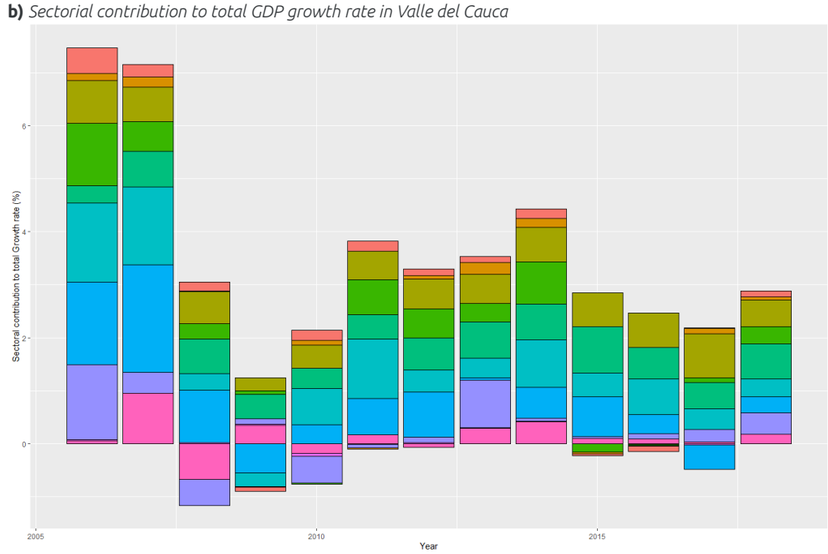
d) *GDP of Coffee Region in constant prices of 2015*



a) *Sectorial contribution to total GDP growth rate in Antioquia*



b) *Sectorial contribution to total GDP growth rate in Valle del Cauca*



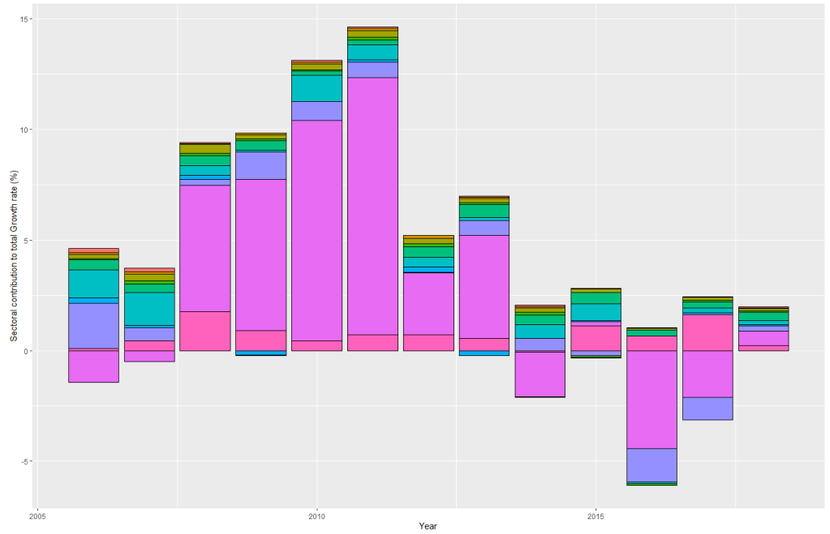
Groups

- Information and Communications
- Public Services (Gas, Electricy and Waste Management)
- Financial and Real State
- Professional, Scientific and Technical Activities
- Social, Community and Personal Services
- Commerce, Transport, Hotels and Restaurants
- Manufacturing Industry
- Construction
- Mining and Quarrying
- Agriculture and Silviculture

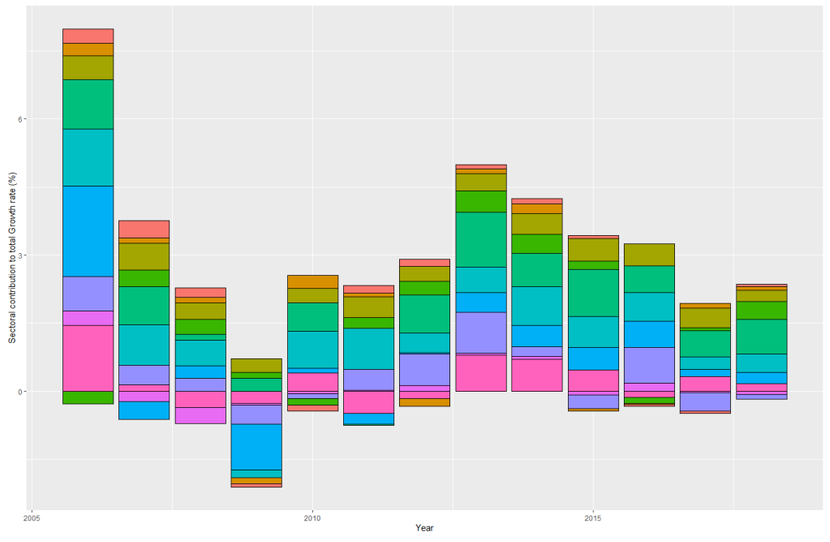
Figure 10
Sectorial contribution to total GDP growth rate in 4 regions: a) Antioquia, b) Valle del Cauca, c) Orinoquia d) Coffee region. (Source: own elaboration on information from DANE, 2018)

Figure 10
Sectorial contribution to total GDP growth rate in 4 regions: a) Antioquia, b) Valle del Cauca, c) Orinoquia d) Coffee region. (Source: own elaboration on information from DANE, 2018)

c) *Sectorial contribution to total GDP growth rate in the Orinoquia*



d) *Sectorial contribution to total GDP growth rate in the Coffee Region*



Groups

- Information and Communications
- Public Services (Gas, Electricy and Waste Management)
- Financial and Real State
- Professional, Scientific and Technical Activities
- Social, Community and Personal Services
- Commerce, Transport, Hotels and Restaurants
- Manufacturing Industry
- Construction
- Mining and Quarrying
- Agriculture and Silviculture

of the GDP in 2016), followed by Agriculture and Silviculture which had a share of 12%. The most important activities among the Agriculture and Silviculture sector are Livestock Farming (48% of total sectorial added value in 2016) and Crop Cultivation (46% of total sectorial added value in 2016). Valle del Cauca, Coffee Zone and Antioquia present a diversified economic composition but with similar trends. In the last decades, these regions experienced relatively high growth rates. The secondary and tertiary sectors are the main contributors of the economic output of these three regions. In 2018, the Agriculture and Silviculture sector only accounted for 5.4%, 9.4% and 5.4% of the total GDP of Valle del Cauca, Coffee Zone and Antioquia, respectively. Within the Agriculture and Silviculture sector, Crop Cultivation activities add the greatest value in these regions, with around 60% of total sector output. Livestock Farming approximately adds the remaining 33%.

5.2 Stakeholders' analysis

The asset check is a data-driven analysis reporting the economic, social and economic conditions of the regions but fails to capture detailed and micro-level information about actual and potential bioeconomy initiatives. The stakeholders' analysis aims to address this gap by complementing the assets check with important bottom-up information. For this purpose, we surveyed key regional bioeconomy stakeholders. An initial dataset of more than 600 contact details was compiled as a first estimation of the regional bioeconomy stakeholders population in each region. These stakeholders operate or intend to operate in different bioeconomy sectors (Table 8), and they were invited to participate in our consultation survey, which was open between the end of March and the beginning of April 2021. Stakeholders were contacted via e-mail and telephone, and they were also asked to circulate the survey to other key stakeholders. Participants of the bioeconomy workshop/ conference organized by Uniandes and Humboldt Institute in late March 2021 were also invited to complete the survey.

Table 8
List of bioeconomy stakeholders

Note: Stakeholders could participate in more than one sector.

Sector	Coffee Zone	Orinoquía	Valle del Cauca	Antioquia
Agriculture	24	45	69	43
Forestry, wood extraction and non-timber forest products	13	5	5	6
Food and beverages	4	3	19	10
Medicine and human health	13	1	14	17
Green chemistry and industrial biotechnology	8	2	22	20
Energy solutions	4	5	19	9
Bio-intelligence	8	0	6	8
Biodiversity and ecosystem services	82	120	25	33
Ecological engineering	5	3	15	15
Not identified	2	4	9	14
Total stakeholders	157	184	188	166

A total of 167 usable questionnaires were collected[5], of which 39 were active stakeholders in Valle del Cauca, 52 in the Orinoquía, 43 in the Coffee Zone, 42 in Antioquia and 58 in other regions[6]. Respondents took on average 51 minutes (25 SD) to complete the survey. The questionnaire was organized in four sections (complete survey is in Appendix III):

1. Characteristics of stakeholders: general information of the respondents such as contact information, job role, typology and location of the company or organisation, and status of their bioeconomy operations (existing or planning).

2. Bioeconomy experience: general information of key-stakeholder bioeconomy experience.

    - Current bioeconomy projects and their performance: main sectors and sub-sectors of the currently undertaken bioeconomy operations, information about turnover, employees, past and future growth prospect, usual origin of labour and capital inputs, and reliance on different forms of capital.

    - Planned bioeconomy projects: main sectors and sub-sectors of the planned bioeconomy operations, prospective turnover, employment, investment, expected origin of labour and capital inputs and expected reliance on different forms of capital.

3. Regional assessment of bioeconomy opportunities: region-specific valuation of the priorities, requisites and limitations for the regional bioeconomy development.

4. Other key stakeholders in the regions: a collection of contact information of other relevant stakeholders already operating or planning to operate in the regions.

Characteristics of stakeholders

Table 9 portrays the distribution of bioeconomy sectors among the surveyed stakeholders. In all regions, Biodiversity and Agriculture are the prevailing sectors; with a respective stakeholder total participation of 46.7% and 41.3%. These two leading sectors gain particular importance in Orinoquía and Valle del Cauca. Green chemistry is also a leading sector, particularly in the Coffee Zone and Valle del Cauca. Many stakeholders are also working in Ecological Engineering, especially in the Coffee Zone. Finally, in the Orinoquía and Valle del Cauca there is an important number of actors operating in the Food and Beverages sector.

5 The initial dataset consisted of 338 responses, those that did not complete at least two of the four sections of the survey were not considered in the analysis.

6 Respondents could be key stakeholders in more than one region.

Sector	Type of operation	Antioquia	Coffee Zone	Orinoquía	Valle del Cauca	All regions
Biodiversity	Operating	30.9	34.9	53.8	43.6	40.7
	Planning	7.1	2.3	5.8	2.6	6.0
	Total	**38.0**	**37.2**	**59.6**	**46.2**	**46.7**
Agriculture	Operating	38.1	34.9	53.8	51.3	35.9
	Planning	2.4	9.3	1.9	5.1	5.4
	Total	**40.5**	**44.2**	**55.7**	**56.4**	**41.3**
Ecological Engineering	Operating	16.7	20.9	21.1	17.9	24.5
	Planning	4.8	7.0	1.9	2.6	5.4
	Total	**21.5**	**27.9**	**23.0**	**20.5**	**29.9**
Green Chemistry	Operating	23.8	27.9	13.5	28.2	18.0
	Planning	0.0	4.6	1.9	2.6	2.4
	Total	**23.8**	**32.5**	**15.4**	**30.8**	**20.4**
Bioenergy	Operating	11.9	13.9	15.4	15.4	18.0
	Planning	4.8	2.3	0.0	0.0	1.8
	Total	**16.7**	**16.2**	**15.4**	**15.4**	**19.8**
Food and Beverages	Operating	11.9	13.9	23.1	23.1	15.6
	Planning	0.0	2.3	1.9	0.0	1.2
	Total	**11.9**	**16.2**	**25.0**	**23.1**	**16.8**
Medicine and Human Health	Operating	14.3	18.6	5.8	7.7	13.2
	Planning	2.4	2.3	0.0	0.0	1.2
	Total	**16.7**	**20.9**	**5.8**	**7.7**	**14.4**
Silviculture	Operating	4.8	4.6	9.6	2.6	4.8
	Planning	2.4	4.6	1.9	2.6	1.2
	Total	**7.2**	**9.2**	**11.5**	**5.2**	**6.0**
Biointelligence	Operating	7.1	4.6	0.0	10.3	3.6
	Planning	0.0	2.3	0.0	0.0	0.6
	Total	**7.1**	**6.9**	**0.0**	**10.3**	**4.2**
Other	Operating	16.7	13.9	9.6	17.9	16.2
	Planning	2.4	2.3	0.0	0.0	1.8
	Total	**19.1**	**16.2**	**9.6**	**17.9**	**18.0**

Table 9
Leading bioeconomy sectors per region and type of operation (%)

Notes: Percentage calculated with respect of total active stakeholders in each region. Stakeholders could participate in more than one sector.

In general, around 75% of total surveyed stakeholders are already engaged in the sectors Biodiversity, Agriculture, Green Chemistry and/or Ecological Engineering. Table 10 portrays the most relevant sub-sectors among these four leading sectors. Within the Biodiversity sector, Bioresearch and Development is at the top. Other important Biodiversity sub-sectors are Ecotourism, Bioprospecting, Natural Ingredients and Forest Products (timber and non-timber). Most of the stakeholders active in the Agriculture sector are participating in activities related to Sustainable Agriculture, which is particularly important in the Coffee Zone and Orinoquía. In those two regions, Agroforestry is also a relevant sub-sector. Integrated pest and nutrient management and agricultural Bio-inputs are also very relevant. Within the Ecological Engineering sector, the sub-sector Waste Management is highly relevant in all regions, especially

Sector	Sub-sector	Antioquia	Coffee Zone	Orinoquía	Valle del Cauca	All regions
Biodiversity	Bioresearch and development	55.6	43.8	45.2	61.1	52.6
	Ecotourism and nature tourism	22.2	18.8	25.8	38.9	32.1
	Bioprospecting	33.3	31.3	22.6	27.8	28.2
	Natural ingredients	33.3	31.3	16.1	38.9	26.9
	Forest products	44.4	31.3	35.5	33.3	26.9
	Other	55.6	56.3	51.6	44.4	52.6
Agriculture	Sustainable agriculture	40.9	63.2	62.1	54.5	55.1
	Integrated pest management	40.9	47.4	44.8	50.0	31.9
	Bio-inputs	31.8	42.1	41.4	50.0	36.2
	Bioresearch and development	31.8	36.8	31.0	45.5	33.3
	Agroforestry	22.7	42.1	41.4	36.4	24.6
	Other	50.0	57.9	51.7	59.1	50.7
Ecological engineering	Waste management	75.0	66.7	66.7	75.0	58.0
	Ecological restoration	75.0	41.7	58.3	37.5	38.0
	Bioresearch and development	87.5	41.7	50.0	25.0	38.0
	Other	75.0	83.3	33.3	75.0	66.0
Green Chemistry	Bioingredients	83.3	64.3	75.0	66.7	61.8
	Bioresearch and development	33.3	35.7	50.0	50.0	47.1
	Other	75.0	85.7	87.5	58.3	73.5

Table 10
Leading bioeconomy sub-sectors per region (%)

Notes: Percentages calculated with respect of total stakeholders per sector and region. Stakeholders could participate in more than one sector.

in Antioquia and Valle del Cauca. Also, in Antioquia there are a high number of stakeholders conducting R&D activities within the Ecological Engineering sector. Finally, within the Green Chemistry, there is high participation of stakeholders in the sub-sector Bio-ingredients and Intermediate Products, especially in Antioquia.

In general, about half of the stakeholders (55.7%) work in the private sector. There are not many differences across sectors in terms of the type of ownership. Nevertheless, a higher proportion of NGOs is found within the Biodiversity and Agriculture sectors. In terms of typology of organisations, non-profit organisations (NPO) consolidate a significant share of companies (21.2%), with very small differences across sectors. Family businesses are also relevant especially in the Green Chemistry and Ecological Engineering sector. In addition, in the Agriculture and Biodiversity sector, there is a relatively high representation of corporations (14.5% for Biodiversity, and 17.9% for Agriculture) when compared with the rest of the sectors. Most of the surveyed stakeholders have directive or managerial positions. Professors and researchers are also a considerable share of the respondents, although in the Orinoquía there is a lower proportion of stakeholders with an academic position.

Bioeconomy experience and expectations

To understand the current bioeconomy experience and expectations we asked stakeholders about key operational performance indicators of their business (Table 11). Around 24% of stakeholders work in companies whose 75% to 100% of turnover was dependent on

bioeconomy operations before the pandemic. Companies with a small share of bioeconomy turnover are also significant. Around 25% of organisations invoiced less than 25% of their total turnover in bioeconomy operations. This tendency remains relatively constant across sectors and regions, nevertheless, there are slight differences in certain indicators. Small companies were predominant, with around 50% of stakeholders indicating that their company employed less than 10 workers. A considerable higher share of small bioeconomy operations was found in the Biodiversity sector, especially in the Coffee Zone where 80% of stakeholders operating in Biodiversity work with less than 10 employees. In contrast, the Agriculture sector employs a relatively high number of people Valle del Cauca, as 37% of the surveyed organisations have over 60 employees.

In addition, to understand the impact of the pandemic, we asked stakeholders to report the state of the bioeconomy operations growth during this period. More than 50% of respondents consistently reported operations staying the same or growing.

Table 11
Bioeconomy performance indicators

	All Sectors				
	Antioquia	Coffee Zone	Orinoquía	Valle Cauca	All regions
Proportion of turnover that corresponded to bioeconomy operations before the COVID pandemic					
Less than 10%	17%	6%	9%	11%	**14%**
Between 10% and 25%	6%	8%	9%	11%	**9%**
Between 25% and 50%	3%	11%	9%	3%	**6%**
Between 50% and 75%	11%	14%	14%	6%	**12%**
Between 75% and 100%	37%	36%	34%	33%	**24%**
Do not know	26%	25%	25%	36%	**37%**
Number of workers operating in bioeconomy before the COVID pandemic					
1-10	51%	56%	45%	31%	**49%**
11-20	9%	6%	7%	14%	**9%**
21-40	11%	8%	14%	11%	**7%**
41-60	3%	3%	7%	3%	**2%**
60-100	3%	3%	7%	6%	**4%**
More than 100	11%	11%	7%	14%	**7%**
Do not know	11%	14%	14%	22%	**21%**
COVID pandemic impact on bioeconomy operations (turnover / activities / employees) growth					
Grew	26%	25%	32%	17%	**20%**
Remained the same	34%	36%	36%	36%	**32%**
Decreased	20%	31%	20%	28%	**25%**
Do not know	20%	8%	11%	19%	**22%**
Expected bioeconomy turnover growth in five years					
Less than 10%	3%	3%	2%	8%	**6%**
Between 10% and 25%	43%	28%	34%	43%	**28%**
Between 25% and 50%	5%	28%	19%	5%	**17%**
Between 50% and 75%	14%	17%	11%	8%	**9%**
Between 75% and 100%	8%	6%	9%	5%	**6%**
Do not know	27%	19%	26%	30%	**34%**

It is noteworthy that around 42%, 40% and 38% of stakeholders operating in Biodiversity in Antioquia, Coffee Zone and Orinoquía reported that their organisations increased their bioeconomy activities during the pandemic. Finally, we asked stakeholders about their expectations regarding their organisation turnover growth of bioeconomy operations. Only around 6% of stakeholders argued that they expected a bioeconomy annual growth lower than 10% within the next five years. Most of the stakeholders think that bioeconomy operations will grow between 10% and 50% in the next five years.

Regional assessment of bioeconomy opportunities

In this section we briefly present stakeholders' opinion on priorities, requisites, limitations and outcomes for the regional bioeconomy development. First, stakeholders were asked to indicate which sectors should be prioritised in each region. Table 12 portrays the three most voted sectors per region. Overall, considering both judgements from all stakeholders and only regional subgroups, results are consistent. Bioresearch and Development is the most voted sector to be prioritised in Valle del Cauca, Antioquia and the Coffee Zone. On the other hand, the majority of stakeholders think that Biodiversity and Ecosystem Services should be prioritised in the Orinoquía.

In order to understand the main regional bioeconomy requirements, we asked respondents to report and rank the five main economic, social and environmental requirements to develop their bioeconomy operations in each of the regions. With this information, we calculated indicators of relative environmental, social and economic importance (see Appendix IV). These indicators range between 0 and 1. If the indicator for a requisite has a value of 1, all actors think this requisite is the most important within its category (environmental, social and economic). If a requisite has a value of 0, none of the stakeholders think this characteristic is within the top 5 most important requisites. In the subsections below is presented a brief analysis of the results for each of the considered categories.

Photo by:
Felipe Villegas, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt

Table 12
Bioeconomy sectors to be prioritised in each region

Bioeconomy sectors to prioritise (Including all stakeholders)				
Rank	**Valle del Cauca**	**Antioquia**	**Orinoquía**	**Coffee Zone**
First	Bioresearch and Development	Bioresearch and Development	Biodiversity and Ecosystem Services	Bioresearch and Development
	55.7%	54.5%	65.9%	49.1%
Second	Green Chemistry and Biotechnology	Medicine and Human Health	Agriculture and Livestock Industry	Biodiversity and Ecosystem Services
	51.5%	49.7%	61.7%	47.3%
Third	Food and Beverages	Biodiversity and Ecosystem Services	Bioenergy	Agriculture and Livestock Industry
	47.9%	43.7%	60.5%	46.1%
Bioeconomy sectors to prioritise (Including only stakeholders operating in each region)				
Rank	**Valle del Cauca**	**Antioquia**	**Orinoquía**	**Coffee Zone**
First	Bioresearch and Development	Bioresearch and Development	Biodiversity and Ecosystem Services	Bioresearch and Development
	84.6%	90.5%	88.5%	83.7%
Second	Green Chemistry and Biotechnology	Medicine and Human Health	Agriculture and Livestock Industry	Ecological Engineering
	79.5%	81%	78.8%	76.7%
Third	Agriculture and Livestock Industry	Biodiversity and Ecosystem Services	Bioenergy / Bioresearch and Development	Biodiversity and Ecosystem Services
	71.8%	78.6%	75.0%	67.4%

Economic requisites

The radar charts shown in Figure 11 portray the important indicators for the economic requisites of the four leading sectors[7] for each region. Stakeholders perceive the existence of Bioeconomy Value Chains as highly important in nearly all regions, but there are substantial differences in the degree and extent of its importance across regions and sectors. In Valle del Cauca, this requisite is ranked at the top for all four leading sectors. In Orinoquía, it is considered as the most important requisite for Biodiversity (0.4) and Food and Beverages (0.47). In Antioquia, this requisite is ranked at the top in Green Chemistry (0.42) and Ecological Engineering (0.4).

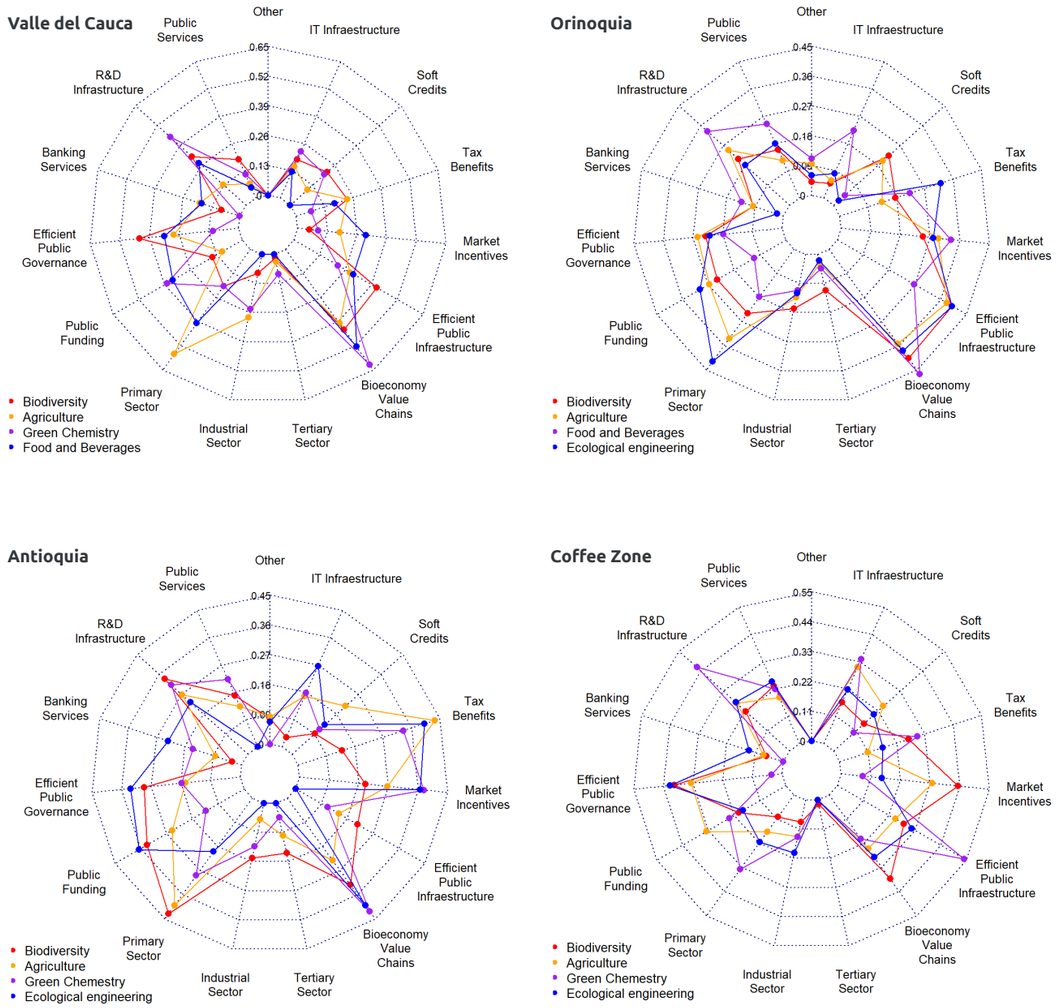
The existence of Efficient Public Infrastructure is considered a priority in the Orinoquía. This is not surprising considering the low highway connectivity of the region. An Efficient Public Infrastructure is also ranked high within the Biodiversity sector in Valle del Cauca

7 Sectors with highest participation share among stakeholders.

(0.42), and within the Green Chemistry sector in the Coffee Zone (0.54). Access to R&D infrastructure is highly valued in the Green Chemistry sector, especially in the Coffee Zone (0.46) and Valle del Cauca (0.44). In addition, in all four regions, Efficient Public Governance is also ranked within the top five most important requisites in the Ecological Engineering and Biodiversity sectors.

In Antioquia, Tax Benefits and Market Incentives are ranked as highly important requisites, especially for the sectors Agriculture, Ecological Engineering and Green Chemistry. Access to Public Funding and Subsidies is also prioritized in Antioquia, especially in the Ecological Engineering (0.37) and Biodiversity (0.34) sector. This indicates the perceived need to design economic instruments and other sources of funding that spur the bioeconomy in these sectors and regions.

Figure 11
Economic Requisites importance indicators by sector and region (Only stakeholders currently operating)

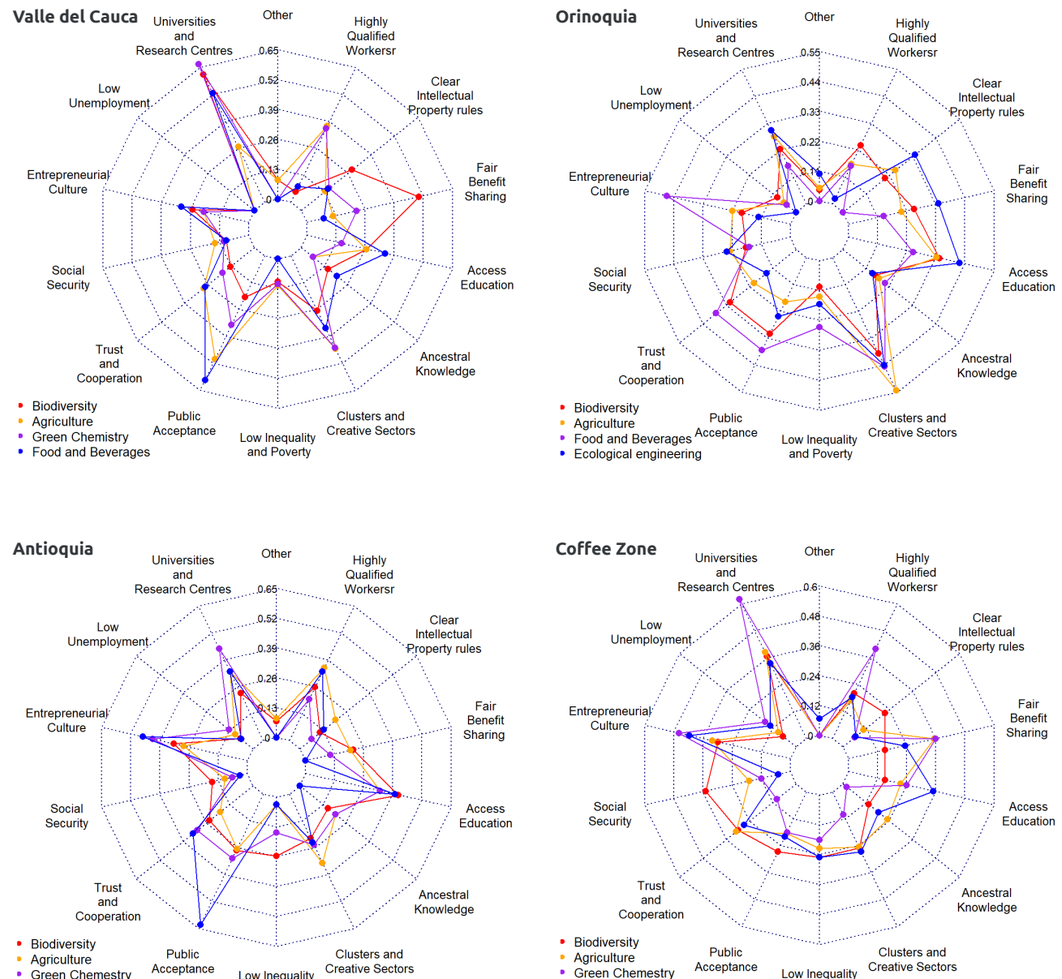


Finally, a strong Primary Sector is highly ranked within the Agriculture sector in Valle del Cauca (0.57), Orinoquía (0.33), Antioquia (0.40), whilst in the Coffee Zone it has negligible importance. The presence of a Strong Primary sector is also considered very important in the Biodiversity sector in Antioquia (0.43), Green Chemistry sector in Coffee Zone (0.34), and Ecological Engineering sector in Orinoquía (0.42).

Social requisites

The regional social requisites indicators are portrayed in Figure 12. Stakeholders in Antioquia highlight the importance of education, workforce and research, as Access to Technical and/or Specialized Education (regional average of 0.37), presence of Highly Qualified Workers (regional average of 0.28) and Universities and Research Centres (regional average 0.32) are weighted as very important in

Figure 12
Social Requisites importance indicators per sector and region (Only stakeholders currently operating)



all the leading sectors. In Valle del Cauca and the Coffee Zone there is a marked prioritisation of Universities and Research Centres, especially in Green Chemistry. In addition, the requisite Highly Qualified Workers is also regarded as very important for the Green Chemistry sector in Valle del Cauca (0.36) and Coffee Zone (0.40). On the other hand, stakeholders in the Orinoquía prioritise the Access to Technical and/or Specialized Education, while consider less important the presence of Universities and Research Centres, and Highly Qualified Workers.

In Orinoquía the presence of Clusters and Creative sectors is considered the most important requisite in nearly all sectors (with a regional average of 0.45), stressing its importance for a bioeconomy development in the region. In Valle del Cauca, Clusters and Creative sectors are also weighted high in Green Chemistry (0.44) and Agriculture (0.45). In addition, an Entrepreneurial Culture is highly ranked in the Coffee Zone and Antioquia, especially in the sectors Ecological Engineering and Green Chemistry. In Orinoquía, Entrepreneurial Culture is also very valued in the Food and Beverages sector.

In Valle del Cauca, a Public Acceptance of the Bioeconomy is highly valued within the Agriculture (0.45), and Food and Beverages (0.6) sector. This requisite is also regarded as very important in the Orinoquía and Antioquia. Another relevant social requisite is Trust and Cooperation, which is thought to be particularly important in the Biodiversity (0.31) and Food and Beverages (0.38) sector in Orinoquía, and in the Ecological Engineering (0.33) and Green Chemistry sector (0.31) in Antioquia. Finally, it is noteworthy the high importance given to a Fair Benefit Sharing in Valle del Cauca and in the Coffee Zone.

To understand the main regional bioeconomy requirements, we asked respondents to report and rank the five main economic, social and environmental requirements to develop their bioeconomy operations.

Environmental requisites

Figure 13 displays the important indicators of the environmental requisites. A common environmental priority across the four regions is the presence of High Biodiversity levels in the Biodiversity (0.29 in Antioquia, 0.28 in Coffee Zone, 0.38 in Orinoquía, 0.49 in Valle del Cauca) and Green Chemistry sectors (0.42 in Antioquia, 0.42 in Coffee Zone, 0.36 in Valle del Cauca). High Biodiversity Levels is also highly valued within the Agriculture sector in the Orinoquia (0.42), Antioquia (0.35) and Coffee Zone (0.25).

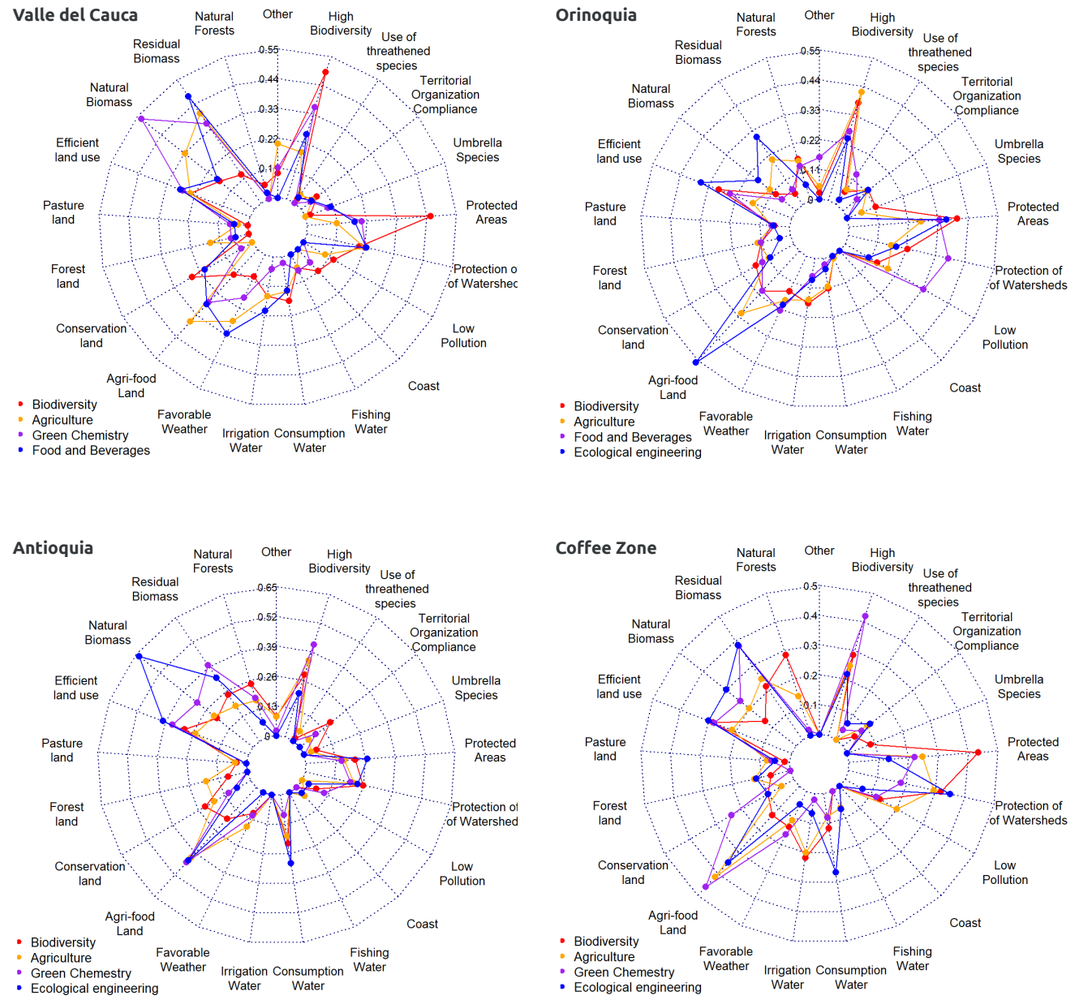


Figure 13
Environmental Requisites importance indicator per sector and region (Only stakeholders currently operating)

The presence of Protected Areas and Biological Corridors is regarded as a priority in the Biodiversity sector. In Antioquia, Protected Areas and Biological Corridors are slightly less valued. In addition, in the Orinoquía, the presence of Protected Areas and Biological Corridors is also ranked high in most of the leading sectors (0.33 Food and Beverages, 0.27 in Agriculture and 0.36 in Ecological Engineering).

In all regions, the presence of Land suitable for Agri-food is ranked as highly important within the Agriculture sector (0.42 in Coffee Zone, 0.42 in Antioquia, and 0.36 in Valle del Cauca and 0.31 in Orinoquia). This requisite is also highly valued in the Ecological Engineering sector and Green Chemistry.

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Stakeholders operating in the Green Chemistry also consider a priority the availability of Residual and Natural Biomass, as these two requisites are ranked within the top five most important environmental features in all regions. The availability of biomass, both residual and natural is also prioritized in the Ecological Engineering sector, especially in Antioquia and Coffee Zone. Finally, in all regions, Efficient Land Use is also considered an important environmental requisite in all sectors, especially Ecological Engineering and Biodiversity.

Capacity buildings requirements

Figure 14 portrays stakeholders' opinion on the main capacity buildings requirements that stakeholders thought all regions needed. Most of the stakeholders agree that all regions need to train the community in Basic Bioeconomy Concepts and Appropriation of Bioeconomy Knowledge. Other topics which were also deemed as key for a successful bioeconomy development were Efficient and Sustainable Use of Natural Resources, Cooperation and Collective Action and Use of Residual Biomass and Bio-waste.

Stakeholders from the Orinoquía indicated the highest amount of training needs. Particularly, most stakeholders agreed that Orinoquía needed training in Adding Value to Bio-resources and Bio-products. Other capacity-building activities, which were also deemed important, were Sustainable Agriculture Practices, New Technologies and Technological Development and Access and Use of Biological Resources. In the Coffee Zone and Antioquia, it is also deemed important to educate the community on how to Add Value to Bio-resources and Bio-products. On the other hand, in Valle del Cauca, Bio-refineries were regarded as an important capacity- building need. ▲

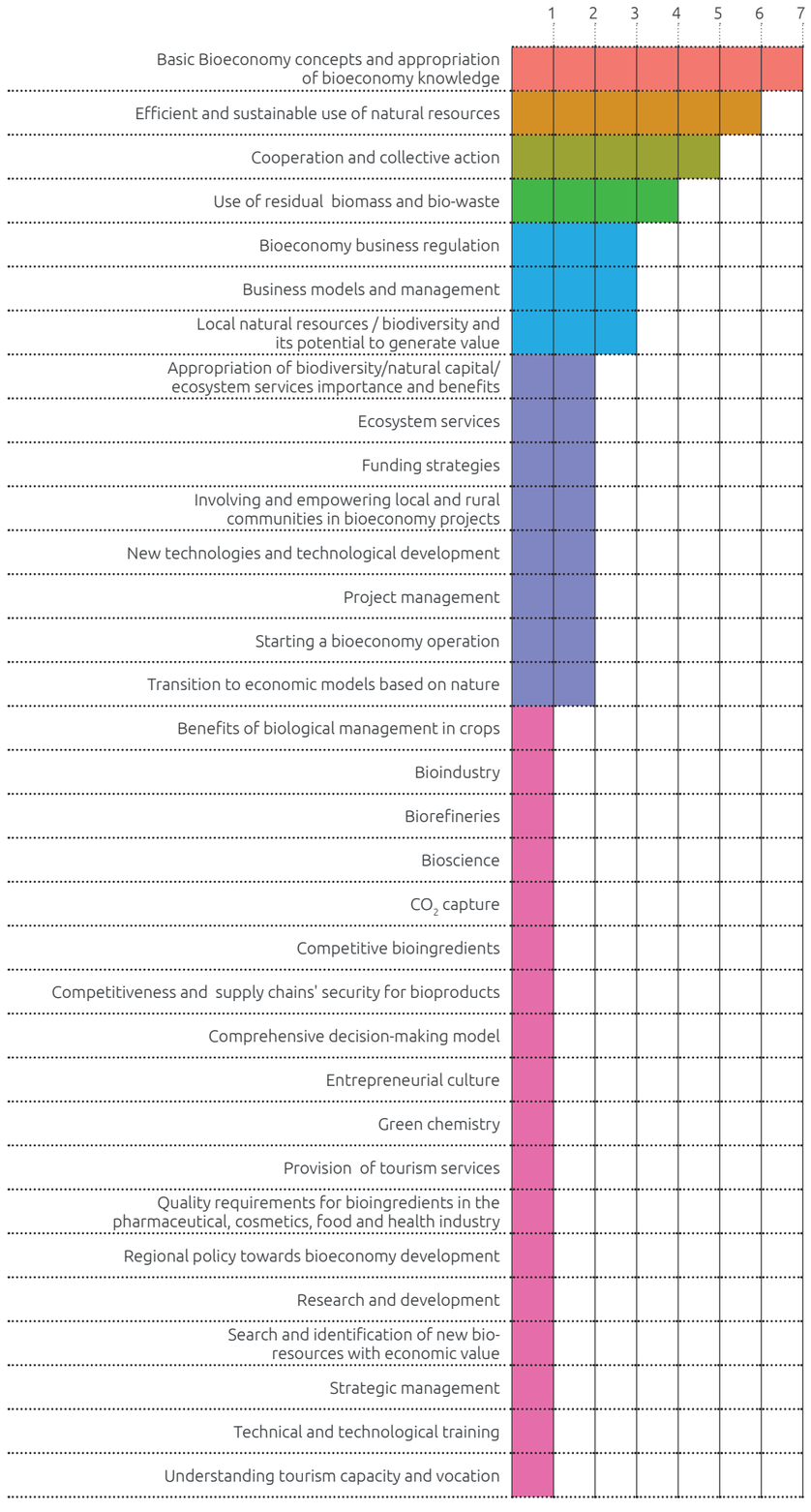

Figure 14
Capacity building requirements in all regions

6. Conclusions

Bioeconomy is a promising sector for highly biodiverse countries like Colombia. Biological resources, innovation, circular economy, traditional knowledge, cultural diversity and high-value local products can all help to promote sustainable inclusive growth for highly diverse regions. At the same time, the promotion of bioeconomic projects requires a collaborative effort by the government, NGOs, private businesses and financial systems, which can impact social, human and economic capital. Our report sets a framework to design and monitor bioeconomy projects via ex-ante and ex-post measures.

The Complementary Account Network defines a set of steps and rules to investigate the current status of the total capital stock in Colombia. The analysis was conducted via a cluster analysis and stakeholders survey, which also monitored changes over time. The data-driven analysis presents the regional differences in terms of economic, social and environmental indicators. The analysis has distinguished five indicator clusters that point to a regionally differential approach. Our results confirm that sustainable bioeconomy investments depend on both a local push and a national/regional pull with appropriate national and international financial and partnerships mechanisms. The data-driven analysis reveals both opportunities and challenges for further bioeconomy development.

Cluster Results

The Coffee Zone and Valle del Cauca already have well-developed agriculture sectors and bioeconomy can complement these activities through investments in agriculture waste or new bio-products investments (e.g. bioenergy or bio-plastic). This will diversify the productivity of the agriculture sector attracting new labor forces and technological innovations, will reduce the environmental impacts on precious natural areas and promote further investment on other bioeconomy activities such as ecotourism or agro-tourism. In addition, in these regions the relatively developed services sector, lower multidimensional poverty levels and higher percentage of land owning farmers also constitute a promising opportunity for bioeconomy development. Land owners can more easily engage in innovative production systems and more sustainable practices if motivated by market forces (e.g. patents, certification, etc). This switch can be further enabled by coordinating and networking the “know-how” base within the regions (e.g. by building on the presence of universities and research centers). This knowledge base could also facilitate green chemistry and food and beverage production in the Valle del Cauca region.

Another region Antioquia, has a highly valuable ecosystem network of wetlands and bioeconomy activities should avoid perturbing these natural assets. The ecotourism and investments in prized natural areas and biodiversity conservation areas might be the sector to be prioritized in this region where economic and social conditions are also favorable. Medicine and human health is also a promising sector for future investment in this region.

The Orinoquía region has a very heterogeneous natural environment and an economic zone. Meta’s economy relies on well-balanced economic sectors and the natural capital is particularly valuable given the presence of key protected areas.

Sustainable bioeconomy investments depend on both a local push and a national/regional pull with appropriate national and international financial and partnerships mechanisms.

The development of ecotourism and complementary agricultural activities (e.g. biogas) represent a valuable bioeconomy option. The northern portions of Orinoquía are instead less developed, heavily reliant on financial support and the social conditions are not ideal. In this zone, the bioeconomy can support a transition to sustainable mining with substantial investments in biodiversity projects and more innovative agriculture activities. In both cases, high investments in human and economic capital are needed to support a rapid uptake of bioeconomy investments.

Survey Results

The stakeholders' survey reveals that multiple firms are already operating across the different sectors of bioeconomy, most predominantly in the sectors of agriculture and biodiversity. There is less developed activity in silviculture, bio-intelligence, medicine and human health. The identified bioeconomy sectors seem to be resilient to economic shocks as the majority of survey respondents, who are active bioeconomic operators, did not experience significant COVID-19 related impacts on their operations. Furthermore, most of the respondents expect an average growth of the company turnover of at least 25% in the next five years. Stakeholders have a clear vision of the promising sectors for the four regions. Bioresearch and Development is ranked first in the Valle del Cauca, Antioquia and Coffee Zone. The Coffee Zone respondents also ranked biodiversity and ecosystem services as good candidate areas for investment. Bioeconomy activities that promote biodiversity and ecosystem services, followed by bioenergy investments were prioritized in Orinoquía.

Our results show how top-down data driven analysis might support the development of bio-economy projects. While at the same time, stakeholders hold diverse opinions that might lead to alternative investment projects. Both types of analysis/data suggest that knowledge hubs, university and research centers, need to strengthen their collaboration with local stakeholders. A stronger network would support the knowledge transfer and instill a culture focused on bioeconomy and natural resources. Public acceptance, collaboration opportunities and entrepreneur attitudes will be the essential elements required to boost and promote bioeconomy.

While the report aims to show a process and a set of tools to design and develop investments in bioeconomy activities, the empirical outcomes resulting from the cluster analysis and the stakeholders survey present limitations. The input data for the cluster analysis are a screenshot of economic, social, and environmental assets and the dynamic effect of changes are neglected as we make the strong assumption of constant effects overtime. Furthermore, the stakeholders' survey was not strictly statistically representative, as a comprehensive list of all bioeconomy actual and prospective operators does not currently exist. The survey data might suffer from self-selection bias and the reported preferences and suggestions just reflect the opinions of interested operators. Nevertheless, it is interesting to observe that stakeholders' recommendations are in line with the capital stocks of the four regions. However, the suggested activities might be too ambitious for some regions where agriculture and biodiversity sectors are already active economic sectors and introducing new sectors (e.g. food and beverage in Valle del Cauca) might require substantial investments.

We would recommend a gentle and diversified transition to bioeconomy. Successful operators in the agri-business sector should be encouraged to diversify their production including complementary activities such as agriculture waste valorization (e.g. bioenergy), ecotourism or eco-learning. Whereas modern agriculture systems, bio-medicine and bio-products can be implemented in disadvantaged locations (e.g. Northern Orinoquia) to support a rapid boost to economic and social conditions. Further development of knowledge hubs and regional and national networking arrangements bringing together private business, research facilities, NGOs and local/national government agencies, are key requirements. ▲

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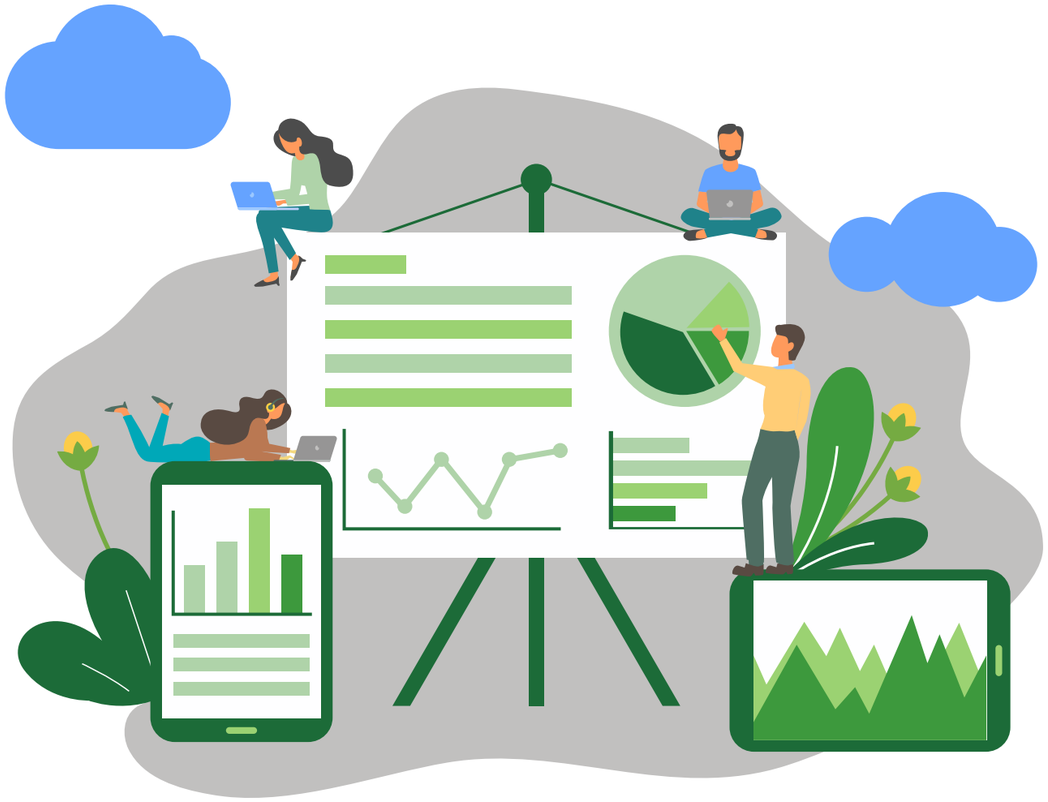

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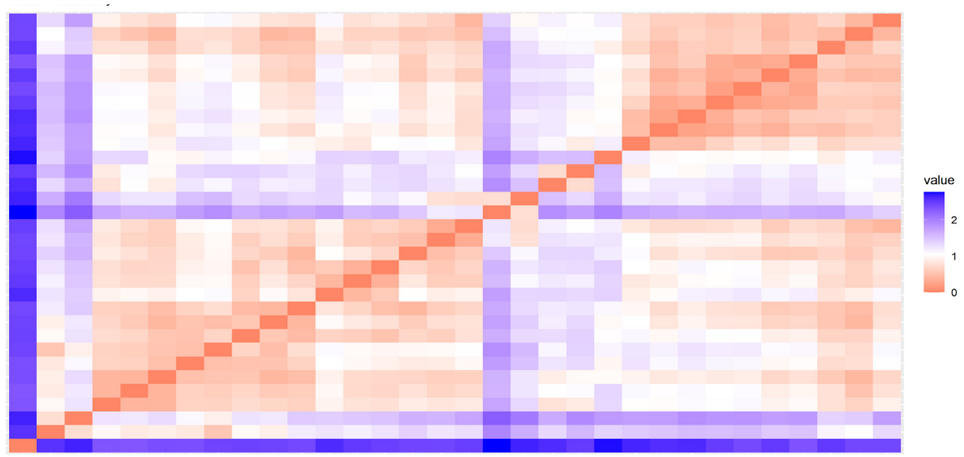
Appendix I – Cluster tendency and number of clusters

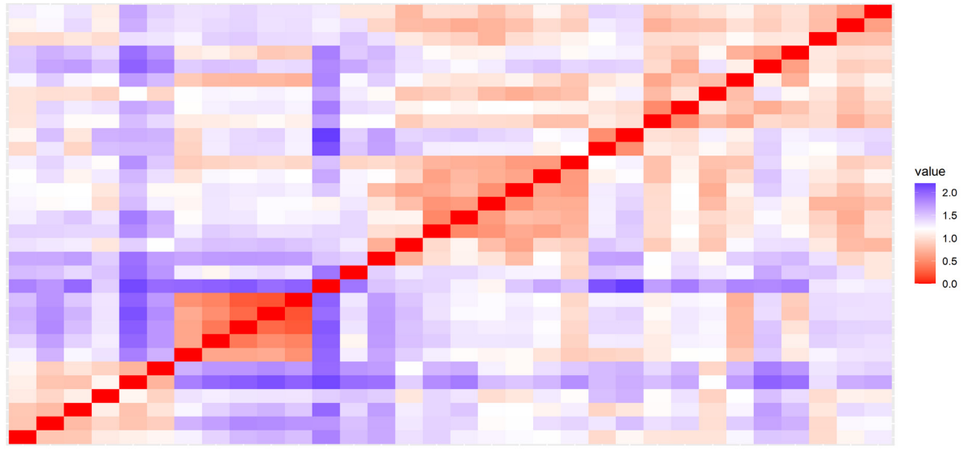
Preliminary assessment of the dataset containing meaningful clusters (i.e., non-random structures) was performed by examining the clustering tendency through the Hopkins statistics and the Visual Assessment of cluster Tendency (VAT) algorithm. The Hopkins statistics is equal to 0.24 for the economic variables, 0.31 for the social variables and 0.35 for the environmental variables. Values are below the threshold of 0.50 for all dimensions, indicating the presence of meaningful clusters. Figures below show results of the VAT algorithm. Red squares indicate similarity, that is a tendency to form clusters, whilst blue squares indicate dissimilarity. VAT shows evidence of a clusterable dataset on each dimension.

Once determined that the data tend to form meaningful clusters, the optimal number of clusters was explored. Figures below show, for each dimension, results of the Elbow method, which looks at the total intra-cluster variation as a function of the number of clusters. The optimal number of clusters should be determined when additional clusters do

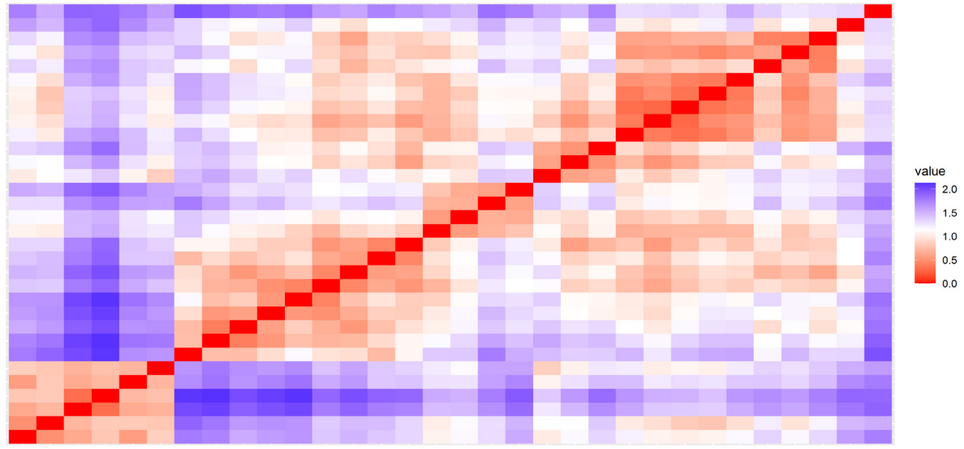
EconTendency



EnvTendency



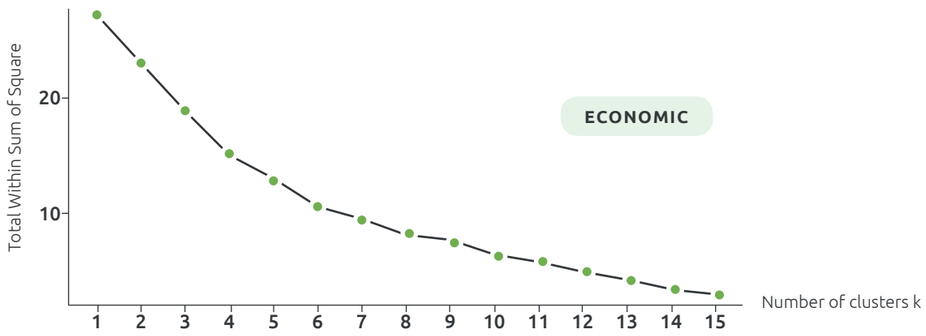
SocialTendency



not improve the total intra-cluster variation. Visually, this means that the point where the line on the graph bends approximates the optimal number of clusters. In our case, the decrease in the intra-cluster variation generally slows when considering between 4 and 6 clusters.

Based on results of the Elbow method, each dimension was analysed imposing a structure with 3 to 6 clusters to assess differences in clustering power when adding or removing clusters. Graphs below show cluster plots for each dimension.

OPTIMAL NUMBER OF CLUSTERS



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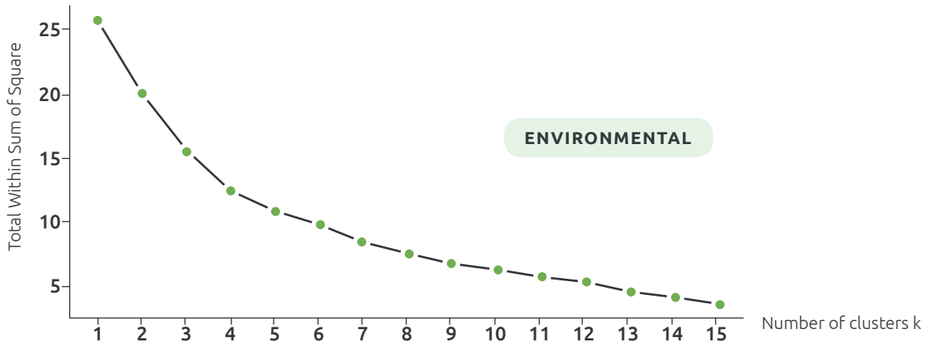

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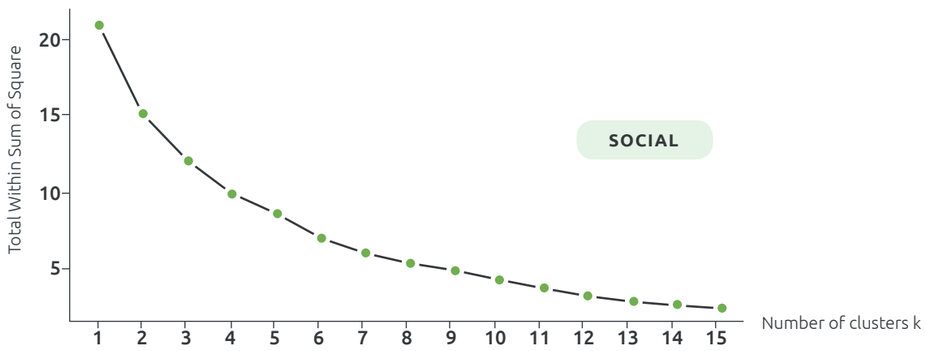
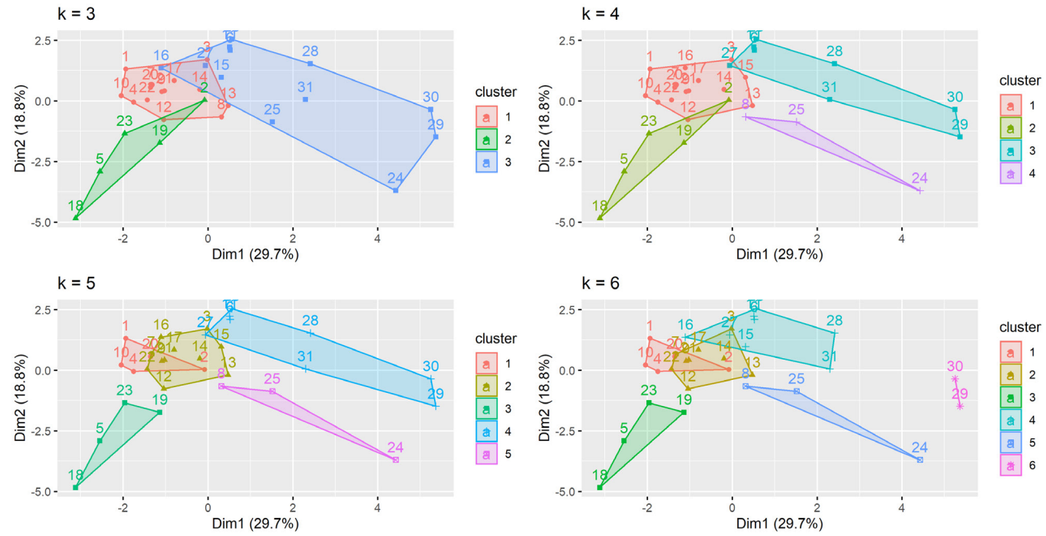
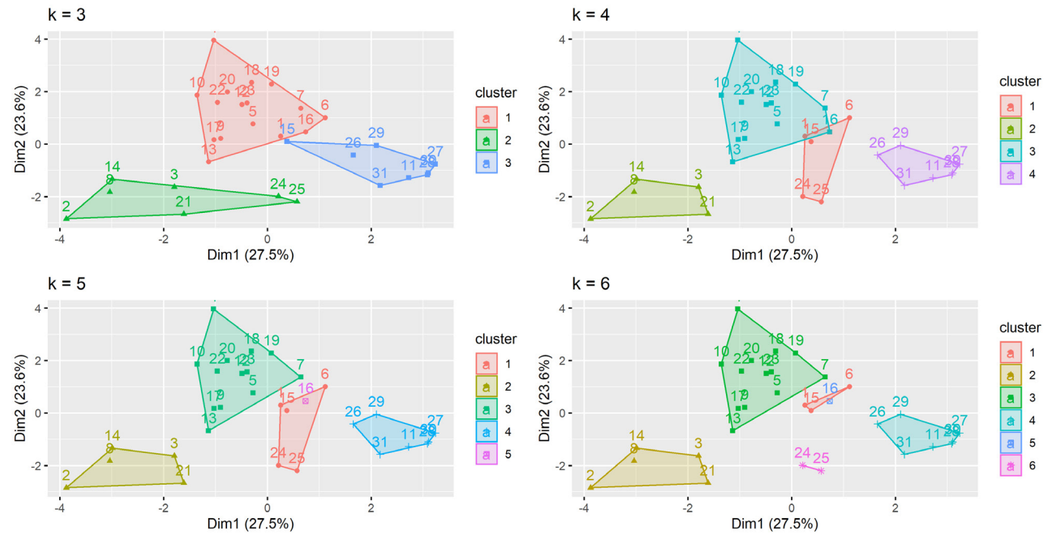
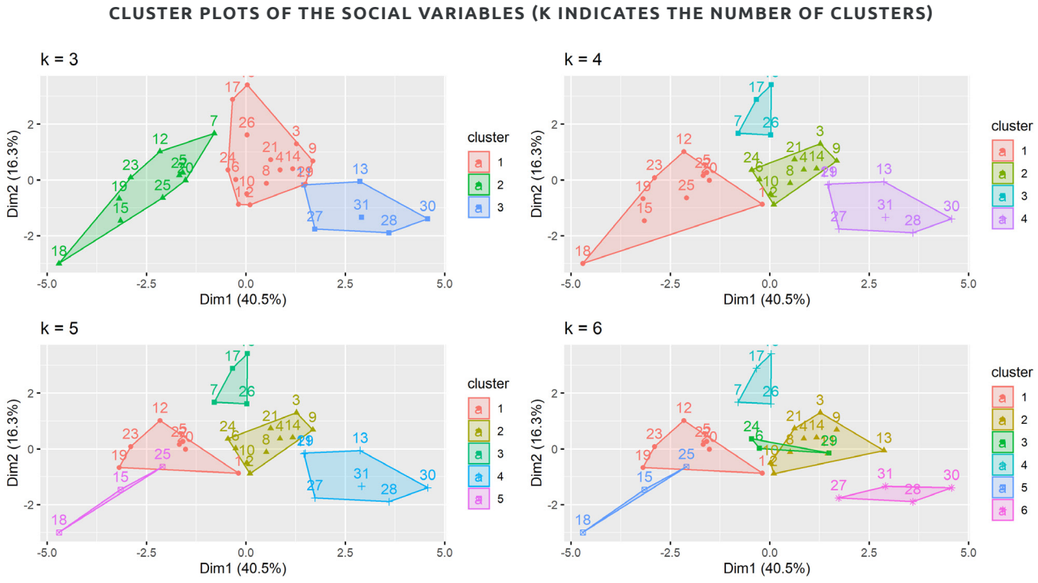


CLUSTER PLOTS OF THE ECONOMIC VARIABLES (K INDICATES THE NUMBER OF CLUSTERS)



CLUSTER PLOTS OF THE ENVIRONMENTAL VARIABLES (K INDICATES THE NUMBER OF CLUSTERS)





Appendix II – Mean values of the variables used in the cluster analysis

Economic Clusters

Cluster	Fiscal transfer ($/capita)	Public debt ($/capita)	GDP Agriculture ($/capita)	GDP Mining ($/capita)	GDP Public services ($/capita)	GDP Services ($/capita)
1	5661.3	786.5	6043.9	2846.7	5435.2	46293.9
2	14473.2	915.3	17513.2	32909.7	6025.8	64867.2
3	23048.2	898.7	37782.7	1949.0	13728.8	177980.2
4	230796.9	2830.9	24567.7	12850.3	5966.0	389359.8
5	80901.0	4264.1	140506.4	381784.6	14567.7	179539.0

Cluster	GDP Industry, construction, transport ($/capita)	Paved highway density (m/km²)	Fluvial density (% area)	Urban population (pop/km²)	Pasture area (% area)	Cereal area (% area)
1	36820.0	257.8	12.7	18406.3	32.9	1.3
2	35367.9	96.1	8.3	1717.5	23.1	3.0
3	102835.7	284.0	1.8	4705.8	19.4	2.0
4	115479.5	7.0	16.0	75.0	9.4	0.3
5	84044.1	65.0	11.3	338.7	56.0	1.8

Cluster	Tubercle, vegetables, fruit area (% area)	Flower, medicinal, forests plants area (% area)	Agrobusiness area (% area)
1	4.6	1.3	4.4
2	5.8	0.7	4.5
3	17.6	3.0	16.4
4	1.1	0.1	3.8
5	1.9	0.2	2.1

Social Clusters

Cluster	Coca crops (ha)	Crime rate 2015/17 (n/100,000pop)	Ownership productive units (% tot)	Multidimensional Poverty Index (% households)	Land Gini Index	Productive units with machineries (% tot)
1	1207.2	457.1	46.8	16.1	0.8	25.9
2	1556.6	308.4	60.4	30.9	0.8	16.8
3	2543.4	269.0	61.8	31.3	0.6	55.2
4	30251.0	292.0	53.0	29.7	0.8	16.0
5	277.7	181.2	27.8	51.8	0.6	24.2

Cluster	Productive units with tech assistance (% tot)	Productive units with credit (% tot)	Internet diffusion (% households)	Higher education (% pop)	Local communities (% area)
1	25.7	12.3	43.1	19.7	0.0
2	9.2	8.7	23.2	15.8	0.1
3	11.1	10.0	13.9	12.0	0.2
4	15.6	14.2	18.1	13.5	0.3
5	8.8	2.3	7.9	9.2	0.7

Environmental Clusters

Cluster	Mean altitude (m)	Water surplus (% area)	Deforestation rate 2014/19 (% forest)	Net GHG emissions (Mton CO_2eq)	Human Spatial Footprint Index (% area)	Protected areas (% area)
1	744.6	98.2	4.6	12.4	26.6	14.5
2	197.1	27.6	7.6	5.1	54.1	4.0
3	1463.9	66.1	2.6	4.6	43.7	17.9
4	328.9	99.7	1.5	3.1	7.1	16.4
5	1918.1	82.0	1.1	6.1	23.5	6.1

Cluster	Pristine forest (% area)	Bird watching (% area)	Dry tropical forest (% area)	Wetlands (% area)	Mangrove (% area)	Páramos (% area)
1	25.5	8.3	0.1	36.5	0.0	1.2
2	24.6	7.7	3.9	26.8	0.7	1.3
3	26.7	11.1	1.1	4.4	0.2	8.2
4	63.8	2.7	0.0	18.8	0.1	0.2
5	47.3	4.6	0.3	21.2	3.7	6.7

Appendix III – Stakeholders' consultation survey

Bioeconomy Cluster pre-workshop survey

INTRODUCTION

Thank you for taking part in the survey for the Colombian Bioeconomy Cluster project.

We really appreciate your help in completing this survey which will take approximately 40 minutes. The aim of the project is to strengthen bioeconomy development opportunities and investments in Colombia considering local needs and potential. Your experience and opinions are crucial to inform the national and local government on the present and future development of Colombian bioeconomy.

This survey is run by the University of Los Andes and the University of East Anglia.

In agreeing to complete this survey, you will be asked to report your current involvement in bioeconomy sectors and productions, express your opinion on future development of bioeconomy sectors in your region, and provide general information on bioeconomy development.

Your participation is strictly voluntary, and you may withdraw at any time. Your responses will be anonymised and stored in password-protected computers and will be available only to researchers with research ethics approval. However, once the data is anonymised there is no way that researchers can identify and remove your record.

For further information you can contact Gaetano Grilli (G.Grilli@uea.ac.uk).

Consent to participate in this study is given by ticking the box below.

☐ I am 18 years old and I tick (check) this box to indicate that I voluntarily consent to take part in this survey.

☐ I do not consent (this ends the survey).

SECTION A – General Information

1. **What is the name of your company/organisation?**

.....

.....

.....

2. **Please could you provide a contact email address of your company/organisation?**

.....

.....

.....

3. **What is your role in the company/organisation?**

.....

.....

4. **How long have you been in this role?**

..... years

..... months

5. **What is the type of ownership of your company/organisation?**

..... Private ownership

..... Public ownership

..... Mixed private/public ownership

..... Community Organisation

..... Non-governmental Organisation

..... Other (specify)

6. What ownership structure has your company/organisation?

..... Family business

..... Sole proprietorship

..... Partnership

..... Corporation

..... Cooperative

..... Non-profit Organisation

..... Other (specify) _____

7. Does your company/organisation operate at local, national, or international scale?

..... Local (municipal or department level)

..... National (whole Colombia)

..... Regional (whole South and Central America)

..... Continental (whole American continent)

..... Global (different countries worldwide)

8. Where is the headquarter of your company/organisation located?

..... In Colombia [Go to Question 9]

..... Outside Colombia [Go to Question 10]

9. If the headquarter of your company/organisation is in Colombia, where it is located?

..... Bogotá, D.C.
..... Amazonas
..... Antioquia
..... Arauca
..... Atlántico
..... Bolívar
..... Boyacá
..... Caldas
..... Caquetá
..... Casanare
..... Cauca
..... Cesar
..... Chocó
..... Córdoba
..... Cundinamarca
..... Guainía
..... Guaviare
..... Huila
..... La Guajira
..... Magdalena
..... Meta
..... Nariño
..... Norte de Santander
..... Putumayo
..... Quindío
..... Risaralda
..... San Andrés y Providencia
..... Santander
..... Sucre
..... Tolima
..... Valle del Cauca
..... Vaupés
..... Vichada

SECTION B – Bioeconomy definition

A sustainable development that balances production, development, and environmental conservation, stimulates potential new economic activity, and ensures natural resources for future generations is an overarching objective for the Colombian government.

The development of bioeconomy sectors and production can help progressing towards this objective.

Among the sectors considered within the bioeconomy definition there are for example bioenergy and bio-fuels, health bio-technology, nature and scientific ecotourism, bio-agri-food and agriculture, bio-prospecting, waste bio-remediation, etc.

10. Does your company/organisation currently operate in a bioeconomy sector or activity?

..... Yes [Go to Section C]

..... No, but is planning to start [Go to Section D]

..... No [End of the survey]

SECTION C – Current bioeconomy activities

In this section you will be asked about the current bioeconomy activities of your company/organisation.

11. Do the current bioeconomy activities and operations of your company/organisation mainly take place in one of the following regions?

..... Antioquia

..... Valle del Cauca

..... Risaralda (Coffee Zone)

..... Quindío (Coffee Zone)

..... Caldas (Coffee Zone)

..... Meta (Orinoquía)

..... Casanare (Orinoquía)

..... Vichada (Orinoquía)

..... Arauca (Orinoquía)

..... Other (specify _____)

12. Which of the following sectors best describes the current bioeconomy activities and operations of your company/organisation?

..... (a) Energy solution

..... (b) Biointelligence

..... (c) Use of biodiversity and ecosystem services

..... (d) Agriculture, livestock and fishing industry

..... (e) Silviculture

..... (f) Food and beverages

..... (g) Medicine and human health

..... (h) Green Chemistry and industrial biotechnology

..... (i) Ecological and environmental engineering (bioremediation, waste management ...)

..... (l) Other (specify _____)

12.1. *[IF answer to question 8 is (a)]* ***What is the specific subsector?***

..... Bio-energy or bio-refinery

..... Ethanol

..... Other bioalcohols

..... Biodiesel

..... Biogas

..... Bio-research and development in energy solutions

..... Other (specify_____)

12.2. *[IF answer to question 8 is (b)]* ***What is the specific subsector?***

..... Omics Studies (Metabolomics, Nutrigenomics) and Population Genetics

..... Bioinformatics and Computer Science

..... Big data and machine learning

..... Artificial intelligence

..... Other (specify_____)

12.3. *[IF answer to question 8 is (c)]* ***What is the specific subsector?***

..... Nature tourism or ecotourism

..... Payment for ecosystem services

..... Bioprospecting (including ancestral and traditional knowledge)

..... Nature scientific tourism

..... Natural Ingredients

..... Forest timber and non-timber products

..... Carbon sinks

..... Productive ecological Restoration

..... Bio-research and development in the use of biodiversity and ecosystem services

Other (specify_____)

12.4. *[IF answer to question 8 is (d)]* ***What is the specific subsector?***

..... Agroforestry

..... No-till farming practices

..... Nanotechnology with agricultural applications

..... Precision farming

..... Integrated pest and nutrient management

..... Sustainable agriculture (organic, sustainable soil management)

..... Bio-inputs (biopesticides, biofertilizers without chemical / industrial processing)

..... Genetic selection methods, reproductive technologies

..... Sustainable fisheries practices

..... Bio-research and development in the agricultural industry

..... Other (specify_____)

12.5. *[IF answer to question 8 is (e)]* ***What is the specific subsector?***

..... Ornamental

..... Paper, timber and fiber products

..... Medicinal plants

..... Plants that exude gums and resin

..... Natural dyes and colorants

..... Bio-research and development in silviculture

..... Other (specify_____)

12.6. *[IF answer to question 8 is (f)]* ***What is the specific subsector?***

..... Functional foods

..... Medicinal foods

..... Nutraceuticals

..... Dietary supplements

..... Gastrobotany

..... Bio-research and development in food and beverages

..... Other (specify_____)

12.7. *[IF answer to question 8 is (g)]* ***What is the specific subsector?***

..... Natural, bioactive and biocosmetic ingredients

..... Biopharmaceuticals, Phytomedicines, Bioprocessed pharmaceuticals

..... Tissue engineering and cell therapy

..... Personalized Medicine / Genomic Medicine / Nanomedicine

..... Biosimilars

..... Bio-research and development in medicine and human healthOther (specify_____)

12.8. *[IF answer to question 8 is (h)]* ***What is the specific subsector?***

..... Bio-Ingredients and intermediate bio-products (enzymes, microorganisms and yeasts)

..... Cleaning and household bio-products

..... Other bio-based materials

..... Bio-polymer/Bio-plastic

..... Bio-Textiles (with industrial / chemical processing)

..... Agricultural bio-inputs (with chemical / industrial processing)

..... Genetically modified organisms

..... Other biomaterials

..... Bio-research and development green chemistry and industrial biotechnology

..... Other (specify_____)

12.9. *[IF answer to question 8 is (i)]* **What is the specific subsector?**

..... Eco-friendly designs

..... Phytoremediation and other types of bioremediation

..... Ecological restoration (soil, land, streams, forests, others)

..... Water collection, treatment, and supply

..... Waste management

..... Bio-inspired products and services

..... Biodesign

..... Biomimicry

..... Bio-research and development in ecological and environmental engineering

..... Other (specify_____)

13. Could you please describe more precisely what those bioeconomy activities and operations are? (Type of services and activities, type of bioeconomy products, etc.)

.....

.....

.....

14. Has your company/organisation been working in its bioeconomy activities and operations for more than 12 months (before the COVID-19 restrictions)?

..... Yes [Go to Question 15]

..... No [Go to Question 18]

15. Considering a typical month/year before the COVID-19 restrictions, what proportion of your company/organisation total turnover is due to bioeconomy activities and operations?

..... Less than 10%

..... 10%-25%

..... 25%-50%

..... 50%-75%

..... 75%-100%

..... I do not know

16. Considering a typical month/year before the COVID-19 restrictions, how many employees work on bioeconomy activities and operations in your company/organisation?

..... 1-10

..... 11-20

..... 21-40

..... 41-60

..... 61-100

..... More than 100

17. Considering the last 12 months with COVID-19 restrictions, did the bioeconomy activities and operations of your company/organisation... (Go to Question 20)

..... They grew (Higher turnover or/and more activities or/and more employees)

..... Stay the same

..... Decreased (Lower turnover or/and fewer activities or/and fewer employees)

..... I don't know

18. Considering the last 12 months, what proportion of your company/organisation total turnover is due to bioeconomy activities and operations?

..... Less than 10%

..... 10%-25%

..... 25%-50%

..... 50%-75%

..... 75%-100%

..... I do not know

19. Considering the last 12 months, how many employees work on bioeconomy activities and operations in your company/organisation?

..... 1-10

..... 11-20

..... 21-40

..... 41-60

..... 61-100

..... More than 100

20. Considering the next five years, what is in your opinion the prospect of growth of the bioeconomy activities and operations of your company/organisation?

..... Less than 10%

..... 10%-25%

..... 25%-50%

..... 50%-75%

..... 75%-100%

..... I do not know

21. How would you classify the employees working on bioeconomy activities and operations in your company/ organization and where they usually come from?

	There are no employees of this type	Few of them come from local area	Around half of them from local area	Most of them come from local area	I do not know
Low qualified employees					
Highly qualified employees					

22. What of the following inputs that use your company/organization for its bioeconomy activities come from the local area?

	It mostly come from the local area	It mostly has national precedence but outside the local area	It mostly has foreign precedence	I do not know
Raw material (biomass, natural resources)				
Processed raw material (chemicals, intermediate bio-inputs)				
General purpose machinery				
Specialized machinery				
General services				
Specialized Services				

23. Considering your company/organisation current bioeconomy activities and operations and the area where they mainly take place, how important is the use of the following?
(Select the appropriate importance on the slider for each option where 1 means “Not important at all” and 10 means “Extremely important”)

Natural resources and ecosystems	1-10
Human capital and knowledge (employees’ qualification, education opportunities, young workforce, etc.)	1-10
Social capital and social context (trust, safety, security, etc.)	1-10
Financial capital and resources	1-10
Network of other economic activities	1-10
Network of other bioeconomy activities	1-10
Manufactured Capital (buildings, machinery, laboratories, etc.)	1-10

SECTION D – Future/prospective bioeconomy activities

In this section you will be asked about the prospective bioeconomy activities of your company/organisation.

24. Will the planned bioeconomy activities and operations of your company/organisation mainly take place in one of the following regions?

..... Antioquia

..... Valle del Cauca

..... Risaralda (Coffee Zone)

..... Quindío (Coffee Zone)

..... Caldas (Coffee Zone)

..... Meta (Orinoquía)

..... Casanare (Orinoquía)

..... Vichada (Orinoquía)

..... Arauca (Orinoquía)

..... Other (specify _____)

25. Which of the following sectors best describes the current bioeconomy activities and operations of your company/organisation?

..... (a) Energy solution

..... (b) Biointelligence

..... (c) Use of biodiversity and ecosystem services

..... (d) Agriculture, livestock and fishing industry

..... (e) Silviculture

..... (f) Food and beverages

..... (g) Medicine and human health

..... (h) Green Chemistry and industrial biotechnology

..... (i) Ecological and environmental engineering (bioremediation, waste management ...)

..... (l) Other (specify _____)

25.1. *[IF answer to question 25 is (a)]*
What is the specific subsector?

..... Bio-energy or bio-refinery

..... Ethanol

..... Other bioalcohols

..... Biodiesel

..... Biogas

..... Bio-research and development in energy solutions

..... Other (specify_____)

25.2. *[IF answer to question 25 is (b)]*
What is the specific subsector?

..... Omics Studies (Metabolomics, Nutrigenomics) and Population Genetics

..... Bioinformatics and Computer Science

..... Big data and machine learning

..... Artificial intelligence

..... Other (specify_____)

25.3. *[IF answer to question 25 is (c)]*
What is the specific subsector?

..... Nature tourism or ecotourism

..... Payment for ecosystem services

..... Bioprospecting (including ancestral and traditional knowledge)

..... Nature scientific tourism

..... Natural Ingredients

..... Forest timber and non-timber products

..... Carbon sinks

..... Productive ecological Restoration

..... Bio-research and development in the use of biodiversity and ecosystem services

..... Other (specify_____)

25.4. *[IF answer to question 25 is (d)]*
What is the specific subsector?

..... Agroforestry

..... No-till farming practices

..... Nanotechnology with agricultural applications

..... Precision farming

..... Integrated pest and nutrient management

..... Sustainable agriculture (organic, sustainable soil management)

..... Bio-inputs (biopesticides, biofertilizers without chemical / industrial processing)

..... Genetic selection methods, reproductive technologies

..... Sustainable fisheries practices

..... Bio-research and development in the agricultural industry

..... Other (specify_____)

25.5. *[IF answer to question 25 is (e)]*
What is the specific subsector?

..... Ornamental

..... Paper, timber and fiber products

..... Medicinal plants

..... Plants that exude gums and resin

..... Natural dyes and colorants

..... Bio-research and development in silviculture

..... Other (specify_____)

25.6. *[IF answer to question 25 is (f)]* **What is the specific subsector?**

..... Functional foods

..... Medicinal foods

..... Nutraceuticals

..... Dietary supplements

..... Novel foods

..... Gastrobotany

..... Bio-research and development in food and beverages

..... Other (specify_____)

25.7. *[IF answer to question 25 is (g)]*
What is the specific subsector?

..... Natural, bioactive and biocosmetic ingredients

..... Biopharmaceuticals, Phytomedicines, Bioprocessed pharmaceuticals

..... Tissue engineering and cell therapy

..... Personalized Medicine / Genomic Medicine / Nanomedicine

..... Biosimilars

..... Bio-research and development in medicine and human healthOther (specify_____)

25.8. *[IF answer to question 25 is (h)]*
What is the specific subsector?

..... Bio-Ingredients and intermediate bio-products (enzymes, microorganisms and yeasts)

..... Cleaning and household bio-products

..... Other bio-based materials

..... Bio-polymer/Bio-plastic

..... Bio-Textiles (with industrial / chemical processing)

..... Agricultural bio-inputs (with chemical / industrial processing)

..... Genetically modified organisms

..... Other biomaterials

..... Bio-research and development green chemistry and industrial biotechnology

..... Other (specify_____)

25.9. *[IF answer to question 25 is (i)]* **What is the specific subsector?**

..... Eco-friendly designs

..... Phytoremediation and other types of bioremediation

..... Ecological restoration (soil, land, streams, forests, others)

..... Water collection, treatment, and supply

..... Waste management

..... Bio-inspired products and services

..... Biodesign

..... Biomimicry

..... Bio-research and development in ecological and environmental engineering

..... Other (specify_____)

26. Could you please describe more precisely what those bioeconomy activities and operations will be? (Type of services and activities, type of bioeconomy products, etc.)

.....

.....

.....

27. Considering your average annual investments, how much of that would your company organisation allocate to the planned bioeconomy activities and operations?

..... Less than 10%

..... 10%-25%

..... 25%-50%

..... 50%-75%

..... 75%-100%

..... I do not know precisely yet

28. What proportion of the total turnover of your company/ organization do you expect to come from bioeconomy operations and activities in the near future?

..... Less than 10%

..... 10%-25%

..... 25%-50%

..... 50%-75%

..... 75%-100%

..... I do not know precisely yet

29. For your planned bioeconomy activities and operations, does your organisation plan to relocate existing employees or hire new personnel?

..... Only relocate existing employees [Go to Question 29.1]

..... Only hire new personnel [Go to Question 29.2]

..... It will be hired new personnel and employees will be relocates [Go to Question 29.1 and 29.2]

..... I do not know precisely yet [Go to Question 30]

29.1. How many existing employees do you expect will be relocated?

..... 1-10

..... 11-20

..... 21-40

..... 41-60

..... 60-100

..... More than 100

..... I do not know precisely yet

29.2. How many new employees do you expect will be hired?

..... 1-10

..... 11-20

..... 21-40

..... 41-60

..... 61-100

..... More than 100

..... I do not know precisely yet

30. Do you expect that the existing employees or the new employees working on bioeconomy activities and operations come from the local area where those activities and operations will take place?

	There are no employees of this type	Few of them come from local area	Around half of them from local area	Most of them come from local area	I do not know precisely yet
Low qualified employees					
Highly qualified employees					

31. Where do you expect that your company/organisation buy/acquire the following inputs for its planned bioeconomy activities and operations?

	It will mostly come from the local area	It will mostly have national precedence but outside the local area	It will mostly have foreign precedence	I do not know
Raw material (biomass, natural resources)				
Processed raw material (chemicals, intermediate bio-inputs)				
General purpose machinery				
Specialized machinery				
General services				
Specialized Services				

32. Considering your company/organisation planned bioeconomy activities and operations and the area where they will mainly take place, how important do you expect will the use of the following be? (Select the appropriate importance on the slider for each option where 1 means "Not important at all" and 10 means "Extremely important")

Natural resources and ecosystems	1-10
Human capital and knowledge (employees' qualification, education opportunities, young workforce, etc.)	1-10
Social capital and social context (trust, safety, security, etc.)	1-10
Financial capital and resources	1-10
Network of other economic activities	1-10
Network of other bioeconomy activities	1-10
Manufactured Capital (buildings, machinery, laboratories, etc.)	1-10

SECTION E – Bioeconomy development in the Cluster areas

The Colombian government is interested in developing new bioeconomy opportunities, specifically focusing on the following strategic regions: Antioquia, Valle del Cauca, Coffee Region and Orinoquia.

In this section you will be asked about your opinion on the requisites and outcomes that you think are important for the development of bioeconomy.

33. Based on your knowledge and experience in the four strategic regions Antioquia, Valle del Cauca, Coffee Zone and Orinoquia, which of the following bioeconomy sectors do you think that should be prioritized in each region?

	Antioquia	Valle del Cauca	Coffee Zone	Orinoquia
Energy solutions				
Bio-research and Development				
Use of Biodiversity/ ecosystem services				
Agriculture and livestock industry				
Silviculture				
Food and Beverages				
Medicine and human health				
Green chemistry and industrial biotechnology				
Ecological and environmental engineering				
I do not know				

34. Considering the four strategic regions of the bioeconomy, where does your company/organization mainly operates or its more interested in operate?

..... Antioquia

..... Valle del Cauca

..... Coffee Zone

..... Orinoquia

35. If your company/organization currently operates or plans to operate bioeconomy in the *selected region of question 34*, what is the stage of the operations/planning?

Defining the business idea	Developing the business plan	Business plan ready but looking for funding/ resources	Operational planning ready but not started yet	Fully operational

The following questions are aimed at understanding what are in your opinion the most important requisites to consider when deciding to invest in the development of bioeconomy activities and operations in the four strategic regions of Antioquia, Valle del Cauca, Coffee Region and Orinoquia.

The requisites are divided considering the three main dimensions of sustainable development, that are economic, social and environmental.

36. In your opinion, what are the five most important economic requisites for developing your current/ planned bioeconomy activities or operations in the *selected region of question 34*? (Please rank the following economic requisites, where 1 is the most important, 2 is the second most important, 3 the third most important, and so on until you classify at least the five most important)

Access to IT and high-tech infrastructures/services	
Reliable public services (energy, water, waste management, etc)	
Access to R&D infrastructures/services	
Access to banking services/resources	
Efficient public governance and planning	
Access to public funding	
Strong primary economic sectors (agricultural, fisheries, forestry)	
Strong industrial sectors	
Strong services sectors	
Existence of important bioeconomy value chains	
Existence of efficient public infrastructures (transport, communication, etc)	
Market incentives	
Tax benefits and exemptions	
Access to soft credit	
Other (specify)	

37. In your opinion, what are the five most important social requisites for developing your current/planned bioeconomy activities or operations in the *selected region of question 34*? (Please rank the following economic requisites, where 1 is the most important, 2 is the second most important, 3 the third most important, and so on until you classify at least the five most important)

Access to highly qualified workers	
Presence of universities and research centres	
Low unemployment levels	
Presence of entrepreneurial culture	
Social security and safety	
Strong social trust and cooperation	
Public acceptance for bioeconomy	
Low inequality and poverty levels	
Existence of creative clusters and sectors	
Presence of local and indigenous knowledge	
Access to technical and/or specialized education	
Fair distribution of benefits (Nagoya protocol)	
Clear rules and incentives of intellectual property, such as patenting	
Other (specify)	

38. In your opinion, what are the five most important environmental requisites for developing your current/ planned bioeconomy activities or operations in the *selected region of question 34*? (Please rank the following economic requisites, where 1 is the most important, 2 is the second most important, 3 the third most important, and so on until you classify at least the five most important)

High levels of biodiversity	
Presence of forest resources (natural forests without intervention)	
Abundance of residual biomass	
Abundance of natural biomass	
Efficient land use planning and management	
Presence of land suitable for pastures	
Presence of land suitable for agri-food	
Presence of land with conservation vocation	
Presence of land suitable for agri-food	
Favourable climate conditions	
Presence of water courses (for irrigation)	
Presence of water courses (for consumption)	
Presence of water courses (for fishing)	
Presence of coastal zone courses	
Protection of watersheds and aquifers	
Low pollution and GHG emissions levels	
Protected areas and biological corridors	
Umbrella species conservation	
Activities in accordance with Territorial Organization Schemes (EOT)	
Use of species in some category of threat (for example CITES)	
Other (specify)	

39. Considering all the requisites that you just ranked, which would you consider more important between economic, social and environmental for the *selected region of question 34*? (Please rank the following economic requisites, where 1 is the most important, 2 is the second most important, 3 the third most important)

Economic	
Social	
Environmental	

The following questions are aimed at understanding what are in your opinion the most important outcomes that a bioeconomy development should produce in the selected region of question 34.

The outcomes are divided considering the three main dimensions of sustainable development, that are economic, social and environmental.

You will be asked to rate the importance of each outcome against the others. The rating will be done by selecting a number on a scale like the one in the example below, where the criteria will be on the two ends of the scale and the numbers represent the intensity of importance of the two criteria. If you select a score of 0, it means that the outcomes are equally important for you. Moving towards one outcome or the other, on the contrary, means that the corresponding outcome is relatively more important for you.

OUTCOME 1	Outcome 1 Extremely Important	Outcome 1 Strongly Important	Outcome 1 Moderately Important	Outcomes are Equally important	Outcome 2 Moderately Important	Outcome 2 Strongly Important	Outcome 2 Extremely Important	OUTCOME 2
	3	2	1	0	1	2	3	

40. Considering the following economic outcomes that a bioeconomy development could in the *selected region of question 34*, which do you think are more important?

Generation of value added and profits	3	2	1	0	1	2	3	Contribution to local economic development)
Generation of value added and profits	3	2	1	0	1	2	3	Development of new value chains
Generation of value added and profits	3	2	1	0	1	2	3	Development of specialised innovation clusters
Contribution to local economic development	3	2	1	0	1	2	3	Development of new value chains
Contribution to local economic development	3	2	1	0	1	2	3	Development of specialised innovation clusters
Development of new value chains	3	2	1	0	1	2	3	Development of specialised innovation clusters

41. Considering the following social outcomes that a bioeconomy development could produce in the *selected region of question 34*, which do you think are more important?

Reduction of poverty and inequality	3	2	1	0	1	2	3	Increase of social trust and cooperation
Reduction of poverty and inequality	3	2	1	0	1	2	3	Development of knowledge and high education
Reduction of poverty and inequality	3	2	1	0	1	2	3	Development of entrepreneurial and business culture
Increase of social trust and cooperation	3	2	1	0	1	2	3	Development of knowledge and high education
Increase of social trust and cooperation	3	2	1	0	1	2	3	Development of entrepreneurial and business culture
Development of knowledge and high education	3	2	1	0	1	2	3	Development of entrepreneurial and business culture

42. Considering the following environmental outcomes that a bioeconomy development could produce in in the *selected region of question 34*, which do you think are more important?

Efficient use of ecosystems and biomass	3	2	1	0	1	2	3	Low level of GHG emissions and pollution
Efficient use of ecosystems and biomass	3	2	1	0	1	2	3	Protection of biodiversity
Efficient use of ecosystems and biomass	3	2	1	0	1	2	3	Sustainable disposal and circularity of waste
Low level of GHG emissions and pollution	3	2	1	0	1	2	3	Protection of biodiversity
Low level of GHG emissions and pollution	3	2	1	0	1	2	3	Sustainable disposal and circularity of waste
Protection of biodiversity	3	2	1	0	1	2	3	Sustainable disposal and circularity of waste

43. Considering all the outcomes that you just scored, which would you consider more between the economic, social and environmental for the *selected region of question 34*?

Economic	3	2	1	0	1	2	3	Social
Economic	3	2	1	0	1	2	3	Environmental
Social	3	2	1	0	1	2	3	Environmental

44. Considering the remaining three strategic regions of the bioeconomy, which do you know the most?

..... Antioquia (Not shown if Antioquia is selected in question 34)

..... Valle del Cauca (Not shown if Valle del Cauca is selected in question 34)

..... Coffee Zone (Not shown if Coffee Zone is selected in question 34)

..... Orinoquia (Not shown if Orinoquia is selected in question 34)

Questions 35 and 43 are repeated but for the region selected in question 44.

45. Do you think that any of the strategic regions (Antioquia, Valle del Cauca, Coffee Zone, Orinoquía) need training to develop their bioeconomy potential?

..... Yes [Go to Question 46]

..... No[Go to Question 47]

46. ¿Which regions require training and in what subjects/topics?

47. Based on your knowledge and experience, do you think there are other companies/organisation that currently have, plan to have, or would be interested in having bioeconomy activities or operations in one or more of those four strategic regions? Please try to list as many relevant companies/organisations as you can. Please add the region, name of the company/organisation and contact information (e.g., email or telephone number).

Region	Company/Organisation name	Phone	Email

48. Would you like to be contacted per email to receive information of other activities of the cluster such as advances and training opportunities?

..... Yes (Please write your email) _____

..... No

Appendix IV – Requisites' importance indicator

Economic Requisites importance indicator per leading sectors and region (Only stakeholders currently operating in each region)

	Antioquia				Coffee zone				Orinoquia				Valle del Cauca			
	Biod	Agri	Green Chem	Eco Eng	Biod	Agri	Green Chem	Eco Eng	Biod	Agri	Food	Eco Eng	Biod	Agri	Green Chem	Food
Other	0.08	0.08	0.00	0.07	0.00	0.00	0.00	0.00	0.04	0.10	0.11	0.06	0.00	0.00	0.00	0.00
Public Services	0.17	0.13	0.22	0.00	0.23	0.18	0.22	0.25	0.16	0.12	0.24	0.18	0.18	0.07	0.11	0.05
R&D Infrastructure	0.34	0.27	0.31	0.23	0.22	0.26	0.46	0.27	0.21	0.25	0.33	0.18	0.32	0.13	0.44	0.28
Banking Services	0.03	0.08	0.16	0.23	0.07	0.08	0.00	0.13	0.10	0.10	0.13	0.02	0.08	0.18	0.00	0.18
Efficient Public Governance	0.29	0.17	0.18	0.33	0.40	0.34	0.04	0.42	0.23	0.26	0.18	0.22	0.43	0.28	0.11	0.33
Public Funding	0.34	0.25	0.13	0.37	0.20	0.34	0.24	0.18	0.24	0.27	0.11	0.30	0.15	0.10	0.38	0.35
Primary Sector	0.43	0.40	0.29	0.20	0.10	0.17	0.34	0.22	0.24	0.33	0.18	0.42	0.20	0.57	0.20	0.40
Industrial Sector	0.17	0.05	0.13	0.00	0.08	0.14	0.14	0.20	0.17	0.13	0.11	0.12	0.08	0.28	0.24	0.00
Tertiary Sector	0.15	0.10	0.04	0.00	0.02	0.00	0.00	0.00	0.11	0.03	0.04	0.02	0.02	0.03	0.09	0.00
Bioeconomy Value Chains	0.32	0.23	0.42	0.40	0.38	0.25	0.20	0.28	0.41	0.35	0.47	0.38	0.43	0.40	0.62	0.53
Efficient Public Infrastructure	0.22	0.15	0.11	0.00	0.28	0.25	0.54	0.32	0.40	0.38	0.27	0.40	0.42	0.28	0.22	0.30
Market Incentives	0.20	0.27	0.38	0.37	0.43	0.34	0.08	0.15	0.25	0.30	0.33	0.28	0.05	0.18	0.09	0.30
Tax Benefits	0.14	0.43	0.33	0.40	0.27	0.11	0.30	0.17	0.18	0.13	0.22	0.32	0.23	0.23	0.07	0.18
Soft Credits	0.09	0.22	0.11	0.13	0.15	0.25	0.10	0.20	0.22	0.20	0.04	0.02	0.22	0.10	0.20	0.00
IT Infrastructure	0.03	0.17	0.18	0.27	0.17	0.31	0.34	0.22	0.05	0.06	0.22	0.08	0.18	0.15	0.22	0.13

Social Requisites importance indicator per leading sectors and region (Only stakeholders currently operating in each region)

	Antioquia				Coffee zone				Orinoquia				Valle del Cauca			
	Biod	Agri	Green Chem	Eco Eng	Biod	Agri	Green Chem	Eco Eng	Biod	Agri	Food	Eco Eng	Biod	Agri	Green Chem	Food
Other	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.07	0.04	0.05	0.00	0.10	0.08	0.08	0.00	0.00
Universities and Research Centres	0.23	0.33	0.44	0.33	0.37	0.38	0.62	0.33	0.22	0.28	0.16	0.30	0.62	0.27	0.67	0.53
Low Unemployment	0.07	0.10	0.13	0.07	0.07	0.09	0.16	0.13	0.09	0.06	0.04	0.00	0.00	0.00	0.00	0.00
Entrepreneurial Culture	0.33	0.28	0.42	0.47	0.30	0.32	0.46	0.42	0.18	0.22	0.47	0.12	0.25	0.20	0.20	0.30
Social Security	0.16	0.10	0.07	0.03	0.35	0.17	0.12	0.05	0.17	0.23	0.16	0.24	0.10	0.15	0.11	0.10
Trust and Cooperation	0.24	0.18	0.31	0.33	0.30	0.31	0.10	0.27	0.31	0.20	0.38	0.14	0.13	0.28	0.18	0.28
Public Acceptance	0.27	0.27	0.31	0.63	0.27	0.18	0.18	0.20	0.31	0.18	0.38	0.24	0.20	0.50	0.33	0.60
Low Inequality and Poverty	0.26	0.03	0.16	0.03	0.25	0.22	0.18	0.25	0.10	0.13	0.24	0.16	0.10	0.12	0.11	0.00
Clusters and Creative Sectors	0.21	0.33	0.24	0.23	0.25	0.25	0.10	0.27	0.39	0.54	0.44	0.44	0.27	0.45	0.44	0.35
Ancestral Knowledge	0.16	0.20	0.20	0.00	0.13	0.23	0.02	0.18	0.15	0.17	0.20	0.14	0.15	0.07	0.07	0.20
Access Education	0.41	0.33	0.33	0.40	0.15	0.22	0.24	0.35	0.34	0.33	0.24	0.42	0.27	0.27	0.16	0.35
Fair Benefit Sharing	0.21	0.20	0.11	0.00	0.15	0.35	0.36	0.23	0.25	0.20	0.13	0.34	0.50	0.12	0.22	0.08
Clear Intellectual Property rules	0.11	0.20	0.07	0.13	0.22	0.11	0.06	0.07	0.20	0.25	0.00	0.34	0.28	0.13	0.16	0.15
Highly Qualified Workers	0.26	0.35	0.20	0.33	0.20	0.17	0.40	0.18	0.24	0.16	0.16	0.02	0.05	0.37	0.36	0.08

Environmental Requisites importance indicator per leading sectors and region
(Only stakeholders currently operating in each region)

	Antioquia				Coffee zone				Orinoquia				Valle del Cauca			
	Biod	Agri	Green Chem	Eco Eng	Biod	Agri	Green Chem	Eco Eng	Biod	Agri	Food	Eco Eng	Biod	Agri	Green Chem	Food
Other	0.09	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.16	0.00	0.09	0.20	0.11	0.00
Natural Forests	0.24	0.17	0.18	0.07	0.28	0.14	0.02	0.00	0.16	0.15	0.13	0.06	0.05	0.00	0.00	0.03
Residual Biomass	0.24	0.18	0.40	0.33	0.22	0.25	0.38	0.38	0.05	0.20	0.07	0.30	0.13	0.40	0.36	0.48
Natural Biomass	0.20	0.22	0.31	0.63	0.13	0.20	0.24	0.30	0.10	0.12	0.07	0.18	0.16	0.33	0.53	0.18
Efficient land use	0.30	0.25	0.36	0.40	0.28	0.22	0.28	0.30	0.29	0.15	0.24	0.36	0.24	0.24	0.27	0.28
Pasture land	0.04	0.05	0.00	0.00	0.02	0.08	0.06	0.05	0.06	0.07	0.07	0.06	0.00	0.04	0.07	0.05
Forest land	0.09	0.18	0.00	0.00	0.07	0.12	0.00	0.12	0.11	0.12	0.11	0.04	0.00	0.15	0.07	0.05
Conservation land	0.23	0.18	0.11	0.07	0.10	0.05	0.24	0.10	0.16	0.10	0.13	0.10	0.25	0.00	0.04	0.20
Agri-food Land	0.19	0.42	0.44	0.43	0.13	0.42	0.46	0.35	0.20	0.31	0.20	0.56	0.13	0.36	0.27	0.28
Favourable Weather	0.10	0.17	0.11	0.00	0.13	0.11	0.16	0.05	0.14	0.18	0.22	0.20	0.09	0.27	0.18	0.33
Irrigation Water	0.00	0.00	0.00	0.00	0.22	0.20	0.02	0.07	0.17	0.15	0.07	0.08	0.15	0.15	0.04	0.20
Consumption Water	0.21	0.18	0.09	0.30	0.12	0.08	0.08	0.27	0.11	0.10	0.02	0.04	0.16	0.13	0.02	0.13
Fishing Water	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.07	0.01	0.01	0.00	0.00	0.05	0.05	0.07	0.00
Coast	0.00	0.05	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.07	0.00
Low Pollution	0.07	0.00	0.11	0.03	0.13	0.20	0.12	0.07	0.14	0.18	0.33	0.10	0.13	0.09	0.00	0.00
Protection of Watersheds	0.26	0.22	0.20	0.23	0.32	0.29	0.18	0.35	0.22	0.16	0.38	0.18	0.20	0.22	0.22	0.23
Protected Areas	0.21	0.17	0.16	0.27	0.43	0.25	0.22	0.13	0.40	0.27	0.33	0.36	0.45	0.11	0.20	0.18
Umbrella Species	0.06	0.03	0.00	0.00	0.08	0.00	0.00	0.00	0.11	0.06	0.00	0.00	0.02	0.00	0.09	0.10
Territorial Organization Compliance	0.17	0.05	0.09	0.00	0.05	0.11	0.08	0.12	0.12	0.11	0.07	0.12	0.07	0.05	0.04	0.05
Use of threatened species	0.01	0.05	0.00	0.00	0.00	0.00	0.04	0.07	0.06	0.07	0.13	0.02	0.02	0.04	0.00	0.03
High Biodiversity	0.29	0.35	0.42	0.20	0.28	0.25	0.42	0.22	0.38	0.42	0.27	0.24	0.49	0.18	0.36	0.25

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