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Informing climate policy through institutional collaboration: reflections on the preparation of Colombia's nationally determined contribution

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ABSTRACT
The 2015 Paris Agreement was adopted at the twenty-first session of the Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC). In the run-up to COP 21, most UNFCCC Parties put forward intended nationally determined contributions (INDCs), containing mitigation pledges. These INDCs are now being confirmed as nationally determined contributions (NDCs), as governments formally ratify the Paris Agreement. NDCs are supposed to provide transparent, quantifiable, comparable, and verifiable mitigation objectives. However, there is neither methodological nor data consistency in the way Parties have prepared their NDCs. This article showcases recent collaboration among research, government, and private institutions that contributed to the Colombian NDC. While documenting the novel research, data, and rich web of collaboration that helped the Colombian government prepare the country's NDC, this article links this specific case with the challenges of policy-oriented and interactive models of research. Our experience confirms previous research on the importance of stakeholder interaction, transparency and openness of processes, and willingness to break disciplinary and institutional barriers. In addition, the experience points to the importance of having appropriate available resources and a local institution acting as champion for the project.

POLICY RELEVANCE
The lack of methodological and data consistency in the way parties have prepared their nationally determined contributions (NDCs) can significantly slow down the progress toward limiting global warming below 2 °C above pre-industrial levels. In the meantime, calls for scientists to provide 'usable' information are increasing and the importance of close collaboration between scientists, end-users, and stakeholders is also increasingly acknowledged. In this article we make explicit the process and research challenges faced during what was, in the authors' opinion, the successful collaboration among scientists, governmental, and private institutions that led to the formulation of an essential component of the Colombian NDC. As policy makers move forward with the implementation of their plans and as scientists become increasingly engaged with government planning, it is essential that they are aware of the needs and demands in terms of collaborations, data, resources, and type of results necessary to produce analyses that can be made fully public and can withstand international scrutiny.

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1. Introduction

It is widely acknowledged that climate change represents an urgent and potentially irreversible threat to human societies, and effectively tackling the problem requires the largest possible cooperation among all countries. For this purpose, during the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) held in Warsaw in 2013, the Parties agreed 'to initiate or intensify domestic preparations for their Intended Nationally Determined Contributions (INDCs)' (Decision 1/CP.19). Based on this decision, countries submitted their INDCs, recording individual countries' climate action plans, in the run-up to the twenty-first COP (COP 21), held in Paris, which eventually adopted the 2015 Paris Agreement. The Paris Agreement establishes the collective ambition of the Parties to limit global warming 'below 2 °C relative to pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels.' When Parties formally join the Paris Agreement, they register their INDCs, which then become known as NDCs. These NDCs are supposed to provide transparent and verifiable mitigation objectives.

It has been, however, widely noted that the cumulative effects of the pledged GHG emission reductions will not contain global warming below the 2 °C target and that much greater efforts will be required (Höhne et al., 2017). Countries are encouraged to develop and share their NDCs and collectively take stock of progress in 2018, particularly in relation to progress towards the 2 °C target. Also, countries are expected to submit new NDCs every five years and are encouraged to enhance their action ahead of 2020.

Voluntary cooperation among countries plays a major role in the Paris Agreement. In fact, the Agreement emphasizes the need for all countries to 'promote transparency, accuracy, completeness, comparability and consistency' (Article 4, para 13). However, it is important to note that at this stage there is neither methodological nor data consistency in the way Parties have prepared their NDCs and it will be important for countries to record and share their experience and the method followed to prepare their NDCs. This article makes explicit the process and research challenges faced during what was, in the authors' opinion, a successful collaboration among scientists, governmental and private institutions that led to the formulation of an essential component of the Colombian NDC. It should be noted that the authors were all involved in different capacities in this collaboration. The article demonstrates how novel research and collaboration among institutions were essential for including the agriculture, forestry and other land use sector (AFOLU) in the official document.

This article also documents the challenges faced by researchers as they effectively connect with end-users and it draws direct connections between the theory and practice of policy-oriented and interactive research. There is a relatively long tradition of criticism of traditional research models in which researchers work detached from practitioners and a linear relationship between theory and outcome is assumed. This criticism has spurred an interest in alternative models of research, and concepts such as collaborative and interactive research have been introduced (Adler, Shani, & Styhre, 2004; Reason & Bradbury, 2001). In the meantime, calls for scientists to provide 'usable' information and research funds allocated to projects that aim at informing policy making have increased (Raitzer & Ryan, 2008). In particular, the importance of close collaboration between scientists, end-users, and stakeholders is increasingly acknowledged particularly for issues related to climate change (Agrawala, Broad, & Guston, 2001; Lemos, Kirchhoff, & Ramprasad, 2012; McNie, 2007). The research presented here was designed to have the strongest possible impact on policy but not as an experiment on the implementation of interactive research or policy-oriented research. However, the experience is an instance of close interaction among researchers, end-users, and policy makers and it can be evaluated using these frameworks. Several insights can be drawn *a posteriori*. Previous research indicates that co-production of knowledge generates information that is more apt to supporting management decisions (Lemos et al., 2012; McKinley, Briggs, & Bartuska, 2012; O'Mahony & Bechky, 2008). Furthermore, besides facilitating a greater agreement between users' needs and what scientists can offer, these approaches open dialogues that foster creative solutions (Gough, 2003; Guston, 1999). Our experience confirms propositions and findings of previous research on the importance of sustained stakeholder interaction, transparency, and openness in the engagement process, and willingness to break disciplinary and institutional barriers. In addition, the experience points to the importance of having a local institution acting as champion for collaboration and greater-than-usual flexibility in the use of funds and assessment of a project outcomes.

Given the scarcity of published work on the formulation of NDCs it is hard to assess if the Colombian case is unique. It is certainly typical of the challenges faced by many countries where local and international research institutions are not always capable of translating their science into actual policy decisions. At a time when little empirical evidence exists on how interaction between scientists and decision makers has actually influenced policies and affected the production of science, the Colombian experience becomes relevant as an example of policy-oriented and interactive research that proved useful to governmental policy making.

2. Background

The Biennial Update Report (BUR)[1] containing updates on national GHG inventories for Colombia was developed by the Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM), and it determined that the AFOLU sector represented 58% of total emissions in the country in 2010. At the same time, this sector is considered to have great potential to help reduce emissions while increasing the country's adaptive capacity to climate change and improving its productivity (Figure 1).

Although the agriculture sector represents only 7% of the gross national product, the sector employs 18% of the population (CIA, 2014). According to official government statistics (IGAC, 2013; IAvH, IDEAM, IIAP, INVEMAR, & SINCHI, 2007), 52% of Colombia's 114 million hectares is covered by natural forests, mostly within the Amazon basin but also forests along the Pacific coast and in the northern part of the country. Cultivated pastures and native savannah grasslands make up 26% of the land area. These lands are characterized by cattle grazing with low stocking rates and natural and anthropogenic fires. Cropland is mostly concentrated in the intermountain valleys, making up approximately 4% of the land surface (Figure 2).

Historically, pastureland expansion has been one of the main drivers of deforestation. Estimates of forest clearing for years previous to 2000 suggest that two-thirds of this clearing was due to expansion of pastureland and one-third to cropland (Etter, McAlpine, Wilson, Phinn, & Possingham, 2006). A more recent analysis (Nepstad et al., 2013) suggests that 90% of forest clearing between 2005 and 2010 was due to pastureland development.

Official projections (MADR, 2011) indicate that there will be few changes in cropland area over the coming decades, with the exception of oil palm. Oil palm area is expected to increase substantially due to high demand for palm oil in food products and as a biofuel.

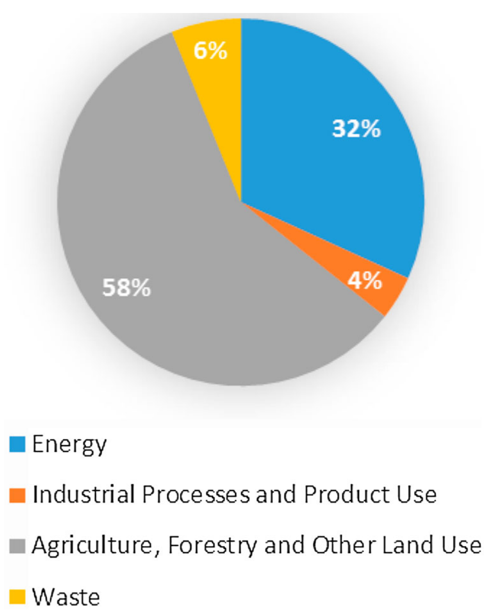

Figure 1. Colombian GHG emissions for 2010. Source: Government of Colombia (2015).

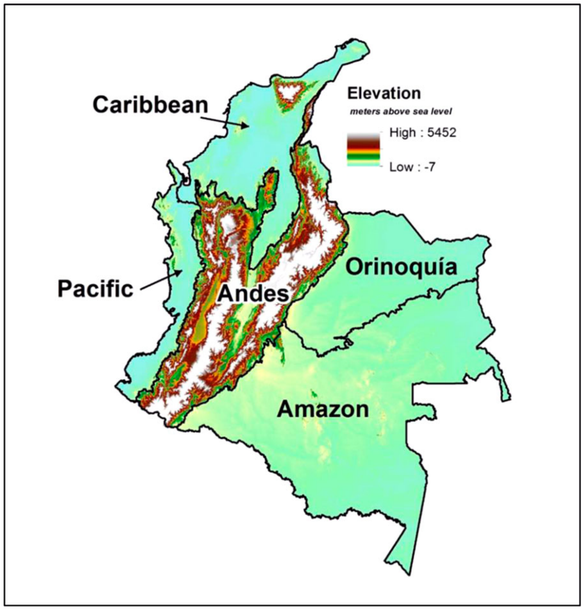

Figure 2. Main regions in Colombia. Source: De Pinto et al. (2016).

3. Policy-oriented and interactive research

The collaboration presented in this article can be considered an example of Policy-oriented Research (POR, Béné, 2015; Walker, Ryan, & Kelley, 2010) and fits the frameworks of interactive and iterative research proposed by Lemos and Morehouse (2005). POR is research for which the ultimate outcome is not about the level of adoption of a specific new technology or the level of innovation, but rather about influencing decision-making processes. It is research that affects choices made by governments or other institutions whose decisions are embodied in laws and regulations. Interactive research attempts to fully internalize the needs of the end-users in its investigations and to build an effective network that favours a sustained flow of information and the sustained participation of scientists and decision makers. This collaborative effort is expected to produce information usable by decision makers (Dilling & Lemos, 2011; Lemos & Morehouse, 2005). Policy-oriented and interactive research also draw from the concepts of action-, and collaborative-research (Adler et al., 2004; Brulin, Ellström, & Svensson, 2003; Reason & Bradbury, 2001; Scott, Skea, Robinson, & Shove, 1999).

The difficulties of engaging in this type of research cannot be underestimated. As Jones (2011) mentions, inducing policy change is highly complex and does not proceed in a linear or rational fashion. Policy processes are shaped by a multitude of interacting forces and acceptance of new information can be based on existing ideologies and is influenced by a myriad of other factors such as pre-existing interests and institutional relationships (Weiss, 1977). Owing to the nature of the policy-making process, research that attempts to influence it evolves differently from what could be considered the traditional research model (Brulin, 1998; Sörlin, 1996) and is subject to a different type and level of scrutiny than traditional peer-reviewed research. The conventional wisdom is that the true impact of POR is difficult to assess (Raitzer & Ryan, 2008) and there is still little empirical evidence of how the interaction between scientists and stakeholders truly transforms the way scientists formulate research questions and carry out research (Lemos & Morehouse, 2005).

There is, however, a growing consensus about the urgency of involving stakeholders in the process of science production, especially within the field of climate research, questions have been raised regarding the extent to which end-users should shape research agendas (Agrawala et al., 2001). In fact, collaborative research has been criticized for being oriented to solve problems that might be too practical and with limited scientific ambition (Seashore, 1976; Svensson & Woodford, 2004) and for running the risk of compromising scientific freedom and neutrality in the definition of research agendas (Scott et al., 1999). Other challenges include the opportunity cost of engaging in this type of research and the drawbacks for scientists' careers of carrying out interdisciplinary research which might sacrifice depth for breadth (Baldwin, 2000; Malone & Rayner, 2001).

Some evidence of successful POR in Latin America exists. In 2009, the Global Development Network (GDN) and the Implementation Centre for Public Policy for Equity and Growth (CIPPEC), published a study (CIPPEC and GDN, 2009) aimed at promoting the debate around how to strengthen the link between research and policies. The study highlights cases in which various types of research entities interacted with policy makers (a local government in Uruguay, the Ministry of Labour in Brazil, the Human Development Secretary of a Locality in Mexico and the Public Administration in Ecuador). The study emphasizes the importance of building trust, the relevance of understanding the interaction between research results and existing ideologies, the availability of mechanisms or institutional spaces that can regulate the interactions among stakeholders, and the asymmetry in available resources such as access to information.

There is also anecdotal evidence that the production of NDCs in some Latin American countries has prompted new and increased levels of participation to civil society, companies, and citizens. However, the literature on this issue is scarce. It has been reported (Edwards, Roberts, Araya, & Retamal, 2015), for example, that Mexico opened the process to civil society groups, Chile involved civil society, academia, and the private sector, and Costa Rica held a workshop with experts hosted by the Ministries of Environment and Energy and Foreign Affairs. In several countries (Chile, Peru, Colombia, and Brazil) stakeholders and research institutions interacted through the South African-led Mitigation Action Plans and Scenarios programme (MAPS, 2015).

4. The institutional setting

In order to understand the process that led to the preparation of the Colombian NDC, it is important to highlight a few events that predate its formulation. Because of its mandate,[2] the Ministry of the Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible, MADS) was the institution in charge of leading the process. The work that laid the foundation started in 2010 when Colombia signed an agreement with the University of Cape Town in South Africa in order to participate in the above-mentioned MAPS programme. The Government of South Africa had commissioned the Energy Research Centre to facilitate a participatory process to construct and analyse alternative emission growth scenarios by engaging with stakeholders across economic sectors and by using the best local and international research. The MAPS programme provided support to several Latin American countries including Chile, Peru, Colombia, and Brazil. By the end of 2014 Chile had constructed more than five emission reduction scenarios, Peru had built its Climate Change Plan with more than 50 mitigation measures, Colombia had consolidated the Colombian Low Carbon Development Strategy (CLCDS) with a portfolio of more than 90 mitigation actions, and Brazil constructed optimization robust models to identify the most cost-effective actions to reduce emissions (MAPS, 2015).

However, not all the analyses led to the same outcomes. For instance, achieving a broad consensus among stakeholders on how to develop mitigation scenarios proved to be difficult in Brazil and as a result government officials decided to start a new process in order to generate the information necessary to produce its NDC. In Colombia, given that the Ministry of Environment led the MAPS initiative, the programme became instrumental to initiating a dynamic and trustful conversation between the government (represented by MADS) and academia (University of los Andes) that continued throughout the formulation of the NDC.

The CLCDS was formally launched on 2012. It proposed a medium and long-term development programme sanctioned by a collaboration among MADS, the Department of National Planning (DNP) and representatives from the sectors that are considered to contribute the most to GHG emissions. One of the lessons learned through this process was that the writing of a mitigation policy would require a robust technical component. Even though the CLCDS process received high-quality support from the Universidad de los Andes, an area of concern was the capacity to model the contribution of the AFOLU sector. It had been determined that a greater confidence in modelling results was necessary for the inclusion of the AFOLU sector in official documents and as a consequence its inclusion in the country's NDC was at stake. Given the share of emissions that originate from this sector, this was perceived as a grave deficiency.

It is in this context that MADS decided to create a partnership with the Universidad de los Andes, the International Food Policy Research Institute (IFPRI) and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) to generate reliable and science-based emissions reduction scenarios for the AFOLU sector.

IFPRI's capacity to perform highly disaggregated spatially explicit analysis of low emission development strategies was seen as a perfect extension of the University los Andes' capacities. CCAFS had engaged with the Government of Colombia since 2013 informing its climate change policies and was perceived as an ideal information broker among institutions. The objective of the collaboration was relatively simple: assess the level of confidence one could have in modelled emission reduction in the AFOLU sector and, contingent on a determination that enough confidence existed, produce ex-ante analyses on viable emission reduction commitments.

Achieving this objective meant creating a research plan jointly with end-users. This included decisions on methods, necessary data, and identifying the subtler research questions underlying the drivers of emission reductions. Developing an extensive and deep engagement with a broad spectrum of institutions and employing their skill sets and perspectives was perceived as paramount to achieve the objective. From this arose the need to utilize what some have defined as a 'boundary organization' (Guston, 1999; Kirchhoff, Lemos, & Kalafatis, 2015), a trusted party capable of creating spaces where frank dialogues around these topics could be carried out. CCAFS in conjunction with MADS played this role and they were able to create and sustain an interactive platform where differing perspectives interacted and where a common understanding of the issues and objective was developed.

Ultimately, the collaboration brought together a group of institutions and agencies that were essential for the appropriate representation of the AFOLU sector (Figure 3).

5. Novel research in support of policy making

Through consultations, the Government of Colombia decided to use a forward-looking baseline (period 2010–2050) rather than a base-year as a reference for the reduction in GHG emissions as many other countries have done for their NDCs. The Parties involved decided that the forward-looking baseline would generate a better understanding of the drivers of growth in emissions and their implications for economic growth. It was also agreed that the two research institutions (IFPRI and Universidad de los Andes) would work independently, utilize different methodologies, but use the same data sets to evaluate reference emissions and simulate the effects of the alternative mitigation plans. The broad range of data sources[3] highlights the contribution of

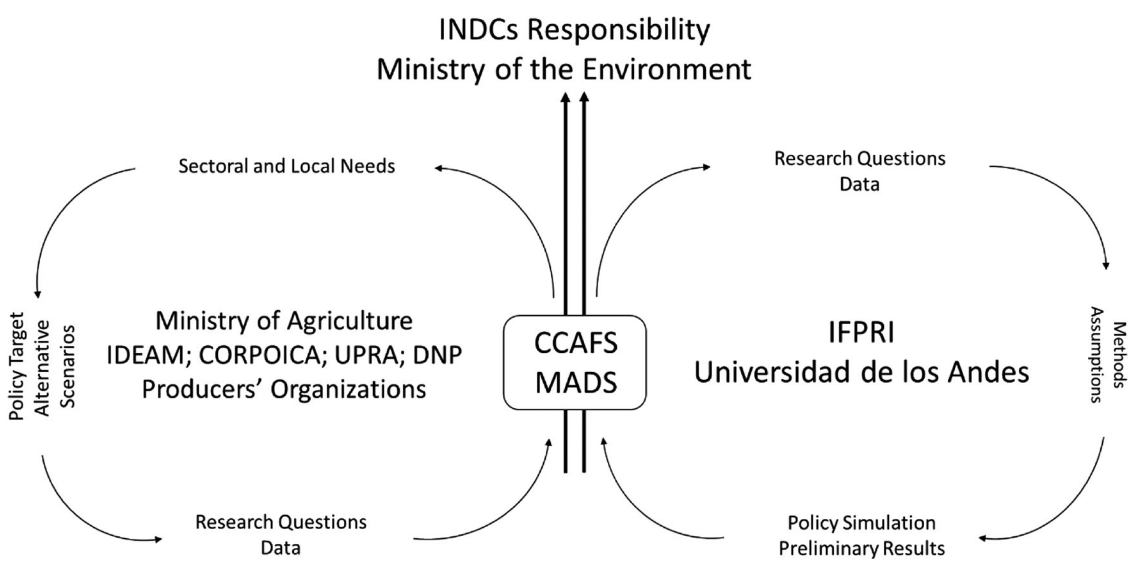

Figure 3. Interacting partners and stakeholders and information flow.

many agencies, along with the high degree of trust across government agencies and coordination necessary to compile the data set. It also highlights the importance of working as an interdisciplinary team to understand the limits and correct use of each data set. Given that one of the objectives was to generate trust in the results, it was agreed that efforts would be made to disclose all the models' underlying assumptions and explain the reasons behind differences in the models' results.

The approaches followed by IFPRI and the Universidad de los Andes were different enough to potentially produce conflicting results and competing insights.[4] The method used by IFPRI followed a typical ex-ante modelling approach, explored in different forms in similar work (e.g. De Pinto et al., 2016; Rutten, van Dijk, van Rooij, & Hilderink, 2014), and relied on three different sub-models to simulate the effects of alternative policies. It used a combination of tier 1, 2, and 3 metrics and although it did not explicitly identify land use transitions, results were geographically disaggregated at the district level. The main strengths of the method used by Universidad de los Andes was the flexibility in incorporating a great variety of data and its compatibility with the IPCC GHG inventory method based on land use transitions. Universidad de los Andes' approach was based on historical trends, expert assessments and assumptions about the behaviour of the sector. The different levels of spatial disaggregation in the two models is responsible for differences in the sources of GHG emissions that the two models track (Table 1).

5.1. Reference scenario and policy simulation results

The reference scenario (baseline) determines the possible reduction in emissions and which climate change mitigation policies are viable. Therefore, the first task for the research teams was to evaluate if a plausible and trusted reference emission pathway could be produced. Table 3 reports baseline GHG emissions as computed by the Universidad de los Andes and IFPRI for the period 2010–2050.[5] The difference in the values reported could be traced back to the different accounting of soil organic carbon and below-ground biomass (Table 1).[6] For a better comparison of the two sets of results, soil organic carbon and below-ground biomass were removed from the computation of emissions in the IFPRI calculations. Total emissions amount to 5802 Tg of CO_2e according to IFPRI's calculations and to 5919 Tg of CO_2e according to Universidad de los Andes. The level of agreement in the reference GHG emissions generated confidence in the modelling capacity of the two research institutions and in the modelling results. In light of this, it was decided that the exploration of the potential for emission reduction was warranted.

The ministry had decided that the NDC should reflect increasingly ambitious policy targets with respect to reduction of emissions. After repeated consultations with interested Parties and stakeholders, it was determined that reducing deforestation rates was a priority. Furthermore, the interested Parties agreed that the options explored should include increased efficiency in the use of existing resources based on rational use of forest plantations, silvopastoral systems, and increased efficiency in cattle raising. Table 2 lists the chosen emissions reduction scenarios.

Table 1. Carbon pools and GHG fluxes accounted in the IFPRI and Universidad de los Andes approaches.

		Carbon pools			GHG fluxes		
Institution	Land use category	Aboveground carbon stock	Below-ground carbon stock	Soil organic carbon	CO_2	N_2O	CH_4
IFPRI	Cropland	YES[a]	YES[a]	YES	YES	YES	YES
	Pasture	YES	YES	YES		YES	YES
	Forest	YES	YES	YES			
	Other land uses	YES[b]	YES[b]	YES			
Universidad de los Andes	Cropland	YES	YES[b,c]	YES[c]		YES[d]	YES
	Pasture	YES		YES[c]			
	Forest	YES	YES[b]	YES[c]			
	Other land uses	YES		YES[c]			

[a]Perennial crops.
[b]Areas with shrub and secondary vegetation.
[c]Only for forest area that transitions to other uses.
[d]Only for areas that do not change use.

Table 2. Emissions reduction scenarios.

Reduction of deforestation		
Scenario 1	0 net deforestation in Caquetá and Guaviare departments in the Amazon region by 2018	
Scenario 2	0 net deforestation in the Amazon region by 2020	
Scenario 3	0 net deforestation in the whole country by 2030	
Additional interventions included in all deforestation reduction scenarios		
	Forests and forestry	*Livestock production*
	Rubber plantation in Amazon and Orinoquía implemented on a total of 240,000 hectares by 2050	Total number of cattle is kept Constant at 24 million after the year 2017
	Forest plantations with various tree species increase by a total 1,139,249 hectares by 2050	Silvopastoral systems are introduced on a total of 553,973 hectares of existing pastureland by 2050
	Restoration of natural forests for a total of 870,000 hectares by 2050	

Table 3 reports the results of IFPRI and Universidad de los Andes' simulated scenarios.[7] Results indicate that the 67 Mt CO_2e per year emission reduction to be achieved by 2030 and committed in the Colombian NDC is well within the country's potential and that the AFOLU sector can contribute significantly to pledged reductions. The lowest potential reduction estimated (scenario 1, Universidad de los Andes) is equivalent to a yearly average decrease in emissions of approximately 37 Mt CO_2e and the highest (scenario 2, IFPRI) is equivalent to a yearly average reduction of 142 Mt CO_2e. Unlike the estimates for the baseline, there are significant discrepancies between the Universidad de los Andes and IFPRI's results. The difference in emissions reduction was traced back to the land-use change dynamics assumed for pastureland, livestock, and deforestation.[8] Results were interpreted as one scenario representing a conservative estimate (Universidad de los Andes) and the other a more optimistic policy outcome (IFPRI).

6. Lessons learned for policy-oriented research

Four elements were essential for the successful uptake of the research produced: sustained stakeholder interaction and openness, usable science and willingness to break disciplinary and institutional barriers, an institution acting as champion for the project, and flexibility in the available resources.

6.1. Sustained consultations and openness

Sustained consultations with policymakers, stakeholders, and advocates were essential to ensure that the relevant policy questions were identified and properly framed. In practice, this meant holding numerous meetings

Table 3. Baseline GHG emissions and effects of achieving alternative policy targets.

Scenarios	Reference GHG emissions period 2010–2050	*Scenario 1*		*Scenario 2*	
Universidad de los Andes	5918 Tg CO_2 e	52,055 hectares of annual avoided deforestation. It only includes avoided deforestation in the *Caquetá and Guaviare areas.*		76,000 hectares of annual avoided deforestation period 2010–2020, 127,000 hectares for the period 2020–2025, and 209,000 hectares for the period 2025–2050.	
		Mitigation	Profit	Mitigation	Profit
		1505 Tg CO_2e	+ 771 Million $US	3248 Tg CO_2e	+ 631 Million $US
IFPRI	7380 Tg CO_2e (5803 Tg CO_2e if SOC and below-ground biomass is removed from the computation)	167,585 hectares of annual avoided deforestation. It includes avoided deforestation in the entirety of the country from reducing the number of cattle heads.		168,195 hectares of annual avoided deforestation. It includes avoided deforestation in the entirety of the country from reducing the number of cattle heads.	
		Mitigation	Profit	Mitigation	Profit
		5246 Tg CO_2e	+ 1.2 Billion $US	5683 Tg CO_2e	+ 1.1 Billion $US

in which objectives, methods, and preliminary results were discussed, explained, and revisited. Similarly important was the willingness to communicate with people with very different backgrounds which favoured the inclusion of ideas and opinions in the modelling itself. This web of relationships was instrumental to compile a data set with the necessary scale and format for the analysis. Ultimately the openness of the process, the flexibility of the methodologies used, the capacity to integrate alternative data sets and the willingness to accept different approaches and to test alternative hypotheses was crucial to convince stakeholders of the importance of participating in the process.

6.2. Usable science and willingness to break disciplinary and institutional barriers

The trust built among the involved Parties was a requirement to break down silos across disciplines and institutions. It was the combination of multidisciplinary ideas and methods that permitted the Parties to generate usable information. This would not have been possible without a genuine integrated network of ideas and tools. This type of engagement required researchers to work at a different pace, sacrificing research time and resources to invest in building and nurturing relationships, and learning ways of communicating science effectively among different disciplines and to non-academic actors. Indeed, the final product was an example of usable science in the sense that it resulted in knowledge that met the needs of and was understood by the user community. Ultimately, the science provided met the thresholds of saliency, credibility, and legitimacy that Cash et al. (2003) determined to be necessary to connect knowledge to action.

6.3. A champion for the project

The commitment from MADS to champion the work was essential to the success of the process. Producing the NDC document was the culmination of a process that had begun at least five years earlier through the MAPS programme and during the formulation of the CLCDS. MADS's choice to use multiple models, the strength of the approaches employed, the capability to explore alternative options, and the robustness of the results reinforced the ministry's leadership role, which in turn strengthened its position to connect government agencies to various productive sectors, academia, and national and international research organizations.

6.4. Flexibility in the availability of resources

It has been repeatedly indicated that POR is inherently non-linear and produces outputs that are difficult to clearly identify and plan for. The case presented corroborates these ideas. One should not underestimate the importance and amount of time dedicated to developing competences, knowledge, and relationships and to fostering a dialogue across institutions based on solid quantitative analysis. The Parties involved needed the flexibility to operate beyond the habitual boundaries of each institution. It was only because the teams involved in this project were able to have access to sufficient resources (funds, personnel, and time) that collaborations between the government, the private sector, and the research community were forged, barriers encountered were broken, and a common understanding of the issue was developed. The availability of resources was able to support the coordinating structure that oversaw the project and that provided the bond that held its various components together.

6.5. Possible drawbacks and benefits for future research

It is difficult at this stage to address questions and possible objections related to end-users shaping the research agenda. The major issue that can be reported in this case was the use of data. It was clear that the choice of which data should be used in the modelling was driven more by how acceptable it was to all partners than by its quality and accuracy. The purpose was clearly one of aligning with official statistics. Given the time constraint, researchers could not perform in-depth sensitivity analyses to explore the effects of the assumptions made and of the functional forms imposed. This is work that would have been performed in a more traditional research setting.

The interactive nature of the work helped identify important areas of intervention. Work needs to be done not only on gathering additional data but also on the appropriate methods to ensure greater data accuracy. It has become also clear that research needs to be undertaken on methods to evaluate the implications of centrally conceived plans for local realities. Finally, consultations have clearly indicated the needs for the analysis to expand and connect the results obtained for the agricultural sector with the other economic sectors of the Colombian economy.

7. Conclusions

Colombia has pledged to reduce 20% of its GHG emissions by 2030 and it may increase to 30% if sufficient international financial support is made available. This is a very ambitious figure and an indication that the country is willing to invest in altering the status quo and embark on a low-emission development path. Colombia's NDC offers it the opportunity to be at the forefront of the debate on climate change and to be among the countries that lead in the implementation of climate change mitigation policies. It is also an opportunity for the country to form a new generation of scientists with a new skill set, and decision makers with a renewed commitment to sustainable growth. Novel research on the effects of specific policy targets directly informed the NDCs. Policy simulations performed by two research institutions returned numerically different results, yet they provided consistent insights to policy makers. There appears to be a large opportunity for increasing the efficiency in the use of land resources in ways that lead to a reduction of emissions. The complex web of relationships between pastureland, cattle raising, and forests plays an essential role in reducing GHG emissions. Intervening in these relationships is difficult but it has clear rewards. The economic valorisation of pastureland and of forests is not only an important step for economic development, but at the same time it can lead to reducing emissions.

It is possible that these insights confirmed ideas, interests, and directions already contemplated by ministries and decision makers, and in this sense questions regarding the extent of the impact of the research presented can be raised. However, doubts and questions whether to include the AFOLU sector in the NDC were real and its ultimate inclusion after the research was conducted is a fact. Notwithstanding questions of attribution, we consider this a successful example of POR.

Notes

1. Biennial Update Reports are reports to be submitted by non-Annex I Parties to the UNFCCC containing updates of national GHG inventories, information on mitigation actions, financial technical and capacity needs and support received. Such Reports provide updates on actions undertaken by a Party to implement the Convention.
2. Among the several functions that MADS executes, the following is included: 'Support all other Ministries in the formulation of public policy under their domain that has environmental and sustainable development implications and establish environmental criteria that should be incorporated in the formulation of these sectorial policies' (Decree 3570 of 2011, Article 2, Civil Service Administration Department, Colombia).
3. The full list of data collected and used to construct the reference scenario (baseline) and policy simulations in reported in the Appendices.
4. More details regarding the modelling approaches used are reported in the Appendices.
5. More disaggregated results are presented in Appendix 3.
6. Universidad de los Andes' accounting was consistent with the Colombian BUR.
7. Note that only results for two scenarios are reported. There were no substantial differences between the results of Scenario 1 (0 net deforestation in Caquetá and Guaviare departments in the Amazon region by 2018) and Scenario 2 (0 net deforestation in the Amazon region by 2020).
8. IFPRI's modelling results indicate that reducing the growth in the number of cattle to a maximum of 24 million heads instead of the projected 31.5 million by 2050 would reduce deforestation by more than 6 million hectares countrywide, 3 million of them located in the Amazon region. Universidad de los Andes estimates effects on deforestation of limiting the growth in the number of cattle only in the Amazon region but not in the remainder of the country.

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Appendices

Appendix 1

Data collected and used to construct the reference scenario (baseline) and policy simulations.

Variables	Year	Geographical resolution	Source
Data used for current reference scenario (Baseline)			
Annual and perennial crop area	2010	Municipality	MADR
Price for crop and meat	2008	National	FAO
Timber price	2008–2010	Regional	Lopez, De La Torre, and Cubbage (2010)
Crop production cost		Regional	Geographical Information System for Planning and Territorial Management (SIGOT)
Crop suitability	2009	10 km resolution	Global Agro-ecological Zones (v1.0) Assessment by IIASA/FAO
Pasture area, forest area	2007	100 m resolution	Leyenda Nacional de Coberturas de la Tierra (IDEAM, 2010)
Elevation	2012	1 km resolution	Harmonized World Soil Database Version 1.2 (HWSD)
Terrain slope	2012	1 km resolution	HWSD V1.2
Soil PH	2012	10 km resolution	ISRIC-WISE
Annual precipitation	1980–2010	1 km resolution	IDEAM
Mean annual temperature	1980–2010	1 km resolution	IDEAM
Population density	2000	1 km resolution	Global Rural-Urban Mapping project by CIESIN/ Columbia University/IFPRI, The World Bank, CIAT
Travel time to cities of 50,000 or more people	2000	1 km resolution	JRC-IES-LRM
Inclusive values for cropland, forest and pasture			Derived from the estimation of the lower-level model
National parks	2012	250 m	RUNAP / SINAP
Afrodescendent area (Tierras de comunidades negras (RESOLUCION 466 DE Marzo 30 de 2012))		250 m	IDEAM
Data used for policy simulations			
Growth rate for commodity price, crop area, and number of slaughtered animal	2010–2050	Price, number of animal: National Area: IMPACT FPU	IMPACT
Climate simulation data	2010–2050	10 km	IPSL GCM model for AR5 SSP2 scenario
Price and crop area growth rate	2010–2050	Price: National Area: IMPACT FPU	IMPACT
Livestock density	2010–2050	National	Instituto Geográfico Agustín Codazzi. Conflictos de uso del territorio Colombiano, 2012

Appendix 2

IFPRI's approach

The main thrust behind the modelling approach followed by IFPRI is in the idea that GHG emissions reduction policies must be financially and politically sustainable in the long-run. Therefore, they must be conceived accounting for global economic forces which produce domestic and global changes in the demand of agricultural commodities and their prices. The modelling framework combines and reconciles economic and biophysical models working at different geographical scales to provide estimations of temporal shifts in GHG emissions, carbon stock, and economic revenues. Three models are linked to achieve this objective. (1) The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT; Robinson et al., 2015), which is a global partial equilibrium agriculture model, which, given a series of changes in productivity, climate, and consumption, generates plausible scenarios for the amount of land in Colombia allocated to each of the 64 modelled crops; (2) an econometric model of land use choices that determines the geographic location of changes in land allocation projected by the IMPACT model (Li, De Pinto, Ulimwengo, You, & Robertson, 2015); (3) the DeNitrification–DeComposition crop model (DNDC; Li, 2007) which estimates GHG emissions from crop production given the biophysical characteristics of the crop production locations identified by the land use model. Figure A1 provides a stylized illustration of the model's interaction. Additional information on the modelling can be found in De Pinto et al., 2016. The overarching goal was to obtain spatially disaggregated results that evaluate the effects of achieving a series of policy targets during the period 2010–2050. Projections are based on gross domestic product and population growth as well as changes in domestic consumption of agricultural commodities but also,

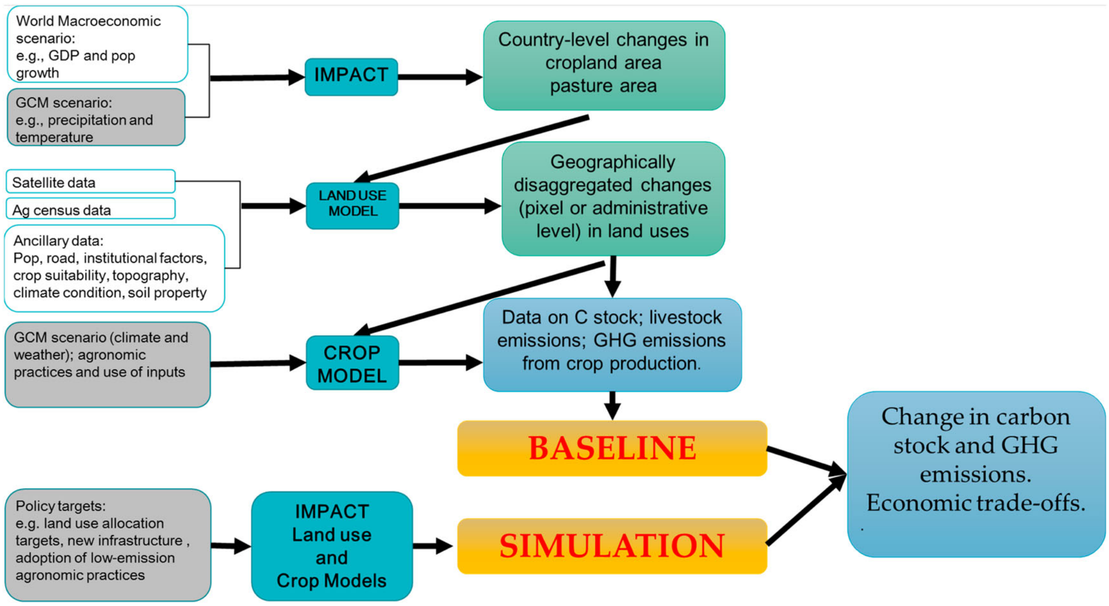

Figure A1. Flow of information and interaction among models in IFPRI's approach. Source: De Pinto et al. (2016).

by construction, they are consistent with global changes in supply and demand of agricultural outputs, trade flows, and changes in commodity prices.

Universidad de los Andes' approach

Universidad de los Andes' approach was based on the 2006 IPCC guidelines and followed the methodology already developed by IDEAM which lump the agricultural and forestry sectors and other land uses in a single group. It accounts for emissions from enteric fermentation and manure management and emissions from agricultural soils and biomass burning. Transition of forest into other land uses was also included in the calculation of GHG emissions.

The year 2010 was taken as base year to be consistent with the country's BUR. IPCC tier 1 and tier 2 methodologies were used with a high level of disaggregation in emissions sources in cattle production (seven emission factors according to age groups) and carbon content for Colombian forests (16 forest types). Emissions from fertilizers (nitrogen oxide) were based on recorded sells countrywide.

Baseline projections were made based on the historical growth rates for agricultural land, livestock, and deforestation. In addition, expectations of sectorial experts were included to account for the results of recent policies. Likewise, the effects of mitigation policies in relation to deforestation, growth in cropland and pastureland, were based on consultations with experts. Figure A2 provides a stylized illustration of the flow of information to obtain the reference scenario (baseline) and projected changes in emissions as a result of alternative policies.

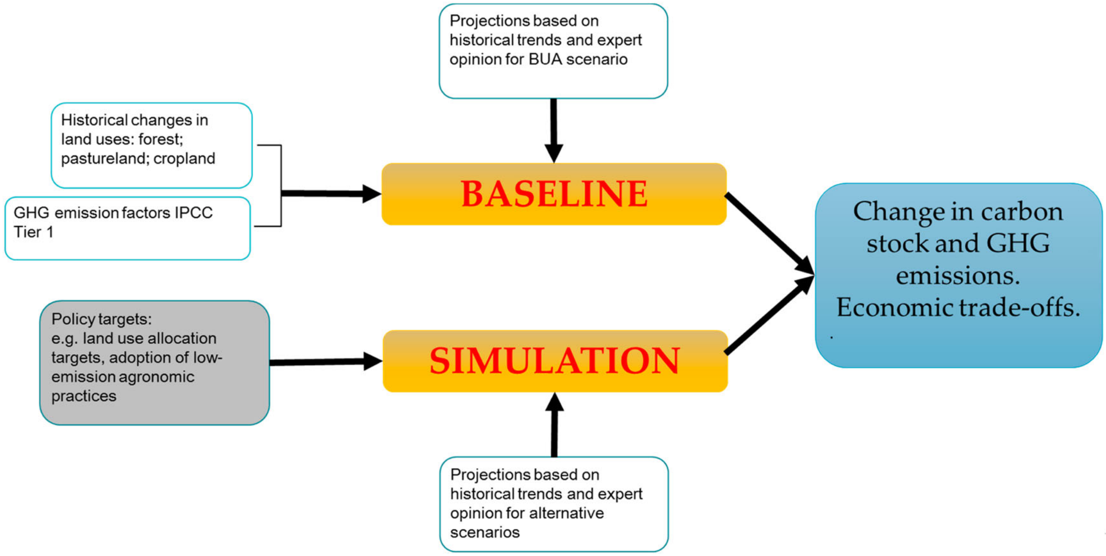

Figure A2. Use of information in Universidad de los Andes' approach.

Appendix 3

GHG emissions and carbon stock changes for the baseline – period 2010–2050.

Category	U. of los Andes GHG emissions (Tg CO_2e)	Sources included	IFPRI GHG emissions (Tg CO_2e)	Sources included
Cattle	1840	Enteric fermentation and manure emissions.	1831	Enteric fermentation and manure emissions.
Cropland	163	N_2O emissions computed from usage of inorganic fertilizer.	155	GHG fluxes from N_2O, CH_4, and CO_2 computed using a crop model.
Forest	3848	Average annual deforestation rate: 208,497.5 hectares, derived from historical rates.	8855 (with SOC and BG-Biomass) 3978 (without SOC and BG-Biomass)	Average annual deforestation rate: 209,000 hectares, derived from modelling results on cropland expansion.
Change in C stock due to increase in pastureland		–	−4672	
Other sources	67	Rice production and fires.	1211	Emissions from other land uses besides forest, pasture and cropland.
Total	5918		7380 (5803 disregarding SOC and below-ground biomass)	