PROJECT ACRNOMYM: TRASSE / ANR-PRCI CONACYT 2017

Trajectories of Social-Ecological Systems in Latin American Watersheds: Facing Complexity and Vulnerability in the context of Climate Change

Project summary

In a world populated by 7.5 billion people anthropogenic change is occurring with increasing rapidity, complexity and uncontrollability (IPCC 2014). To conserve the ecosystems that sustain the livelihoods of the global population we need to understand the speeds and scales at which the drivers of these changes occur, in terms of environmental, climatic, economic, technological, sociocultural, demographic and governance factors (Zou and Wei 2010). Watersheds in the periphery of urban centers (hereafter rural-urban watersheds) are particularly relevant landscapes where to study such changes and climate change vulnerability since urban population drives the pressure and consumption of a large number of rural ecosystem goods and services (e.g. water quantity and quality, food, scenic beauty, water regulation). The social-ecological system framework offers a great potential to better understand the impact, importance, causal mechanisms and interactions between drivers of change and the enabling conditions for long term sustainability of social-ecological systems (SES), but its operationalization is still preliminary. Our scientific objective is to participate in the global academic efforts for operationalizing this framework by advancing in a theory of change for the sustainability of SES through an analysis of social-ecological trajectories. We will work in rural-urban watersheds of Mexico, Colombia and France, which are countries characterised by a contrasting social-ecological drivers of change in terms of urban pressure, governance dynamics, livelihoods productive systems, agri-environmental policies and market demand for ecosystem goods and services. On the other side, their altitudinal gradient and the resulting large variety of land uses, all dependent on the availability of provisioning and regulating water services, makes rural-urban SES watersheds particularly vulnerable to changes induced by ongoing and future climate change stressors. For example, changes on average temperature can modify the distribution of agricultural crops, pushing their altitudinal frontiers to new areas and implying social conflicts or new governance arrangements. In order to identify the key factors that either hinder or facilitate progress towards sustainability –i.e. less vulnerability-, the project Trajectories of Social-Ecological Systems in Latin American Watersheds:

Facing Complexity and Vulnerability in the context of Climate Change (TRASSE) will: identify which are the social (governance, economic, cultural) and biophysical dimensions whose interactions determine the trajectories in time of rural-urban watersheds SES in terms of measurable outcomes such as the flow of ecosystem services –in particular water regulation services-, land management strategies and human well-being. This will allow operationalizing the SES framework at the sub-watershed and watershed scales. Such operationalization will include decomposing the social-ecological dimensions into quantifiable indicators and interactions to link them to a social-ecological vulnerability analysis that copes with sensitivity, exposure and adaptation dimensions.

Second, the indicators related with the governance and actor SES sub-systems will be documented using primary and secondary data. Primary data will be obtained through field interviews and questionnaires with key informants at local and regional levels, in order to understand the evolution of governance arrangements, the evolution of productive systems and infrastructure. Secondary databases will provide with information from agricultural census, types of subsidies and level of poverty and well-being. We will also explore the evolution in the policymix of conservation and development policies. Finally, indicators related to the interactions between governance, actors and the ecosystem will also be documented when related to socio-economic dimensions. Third, ecosystem services and forest quality will be mapped using satellite images of high resolution, as a proxy of ecosystem services. Water regulation will also be documented using rapid appraisal techniques such as the speed of water infiltration. Fourth, by analysing this information on a spatiotemporal basis, TRASSE will be able to explore the trajectories of rural-urban watersheds SES in the last half a century and relate them to climate change vulnerability pathways. Understanding why forest-agriculture trajectories are unfolding in a specific 'direction' is a powerful tool to make stakeholders reflect on how vulnerable these territories are evolving with respect to current scenarios of climate change. This will allow analysing the influence of multi-level polycentric and decentralised governance arrangements in the trajectories observed. Besides, we will explore the commonalities and differences of causal mechanisms in the three case studies to derive a generic theory of change for the sustainability rural-urban watershed SES. Moreover, we will monitor all along the project the way transdisciplinary concepts are understood and which project activities –also called boundary activities- such as team meetings and seminars, fieldwork, participatory scenario making, participate into enhancing the co-construction of interdisciplinary scientific knowledge.

Table 1. Summary of involved scientists.

Partner	Country	Surname	First name	Position	Domain	Person/months	Responsibility in the project
CIRAD**	France	Ezzine-de-Blas	Driss	D.R.	Ecological Economics – environmental policy analysis	12	Co-coordination of the project with a Mexican partner and coordinator of WP2
CIRAD	France	Gond	Valery	D.R.	Forest ecology – analysis satellite images	6	Task leader WP4
CIRAD	France	Le Coq	François	D.R.	Agricultural economics	6	Coordinator WP1
CIRAD	France	Locatelli	Bruno	D.R.	Climate Change adaptation	6	Coordinator WP3
U. de Rennes	France	Ozswald	Johan	M.C.	Spatial statistics	6	Coordinator WP3
U. de Rennes	France	Corgne	Samuel	M.C.	Spatial and multidimensional statistics.	2	Task leader WP3
COLMEX*	Mexico	Perevochtchikova	Maria	Doctor	Ecological geography	12	Co-coordination of the project with a French partner and coordinator of WP2
UNAM-IIEC	Mexico	Ávila-Foucat	Sophie	Doctor	Ecological Economics	6	Task leader WP2 and WP3.
IPN Oaxaca	Mexico	Durán-Medina	Elvira	Doctor	Collective action	4	Task leader in WP1, WP2 and WP3

UNAM – Fac. de Ciencias	Mexico	Almeida-Leñeiro	Lucia	Doctor	Ecology and Ecosystem Services	2	Task leader WP2
UNAM – Instituto de Geografia	Mexico	Pérez-Campuzano	Enrique	Doctor	Economic analysis and Geographic Information System	2	Task leader WP1
COLMEX	Mexico	Hernández-Flores	José-Alvaro	Doctor	Behavioral economics	4	Task leader WP1 and WP2
U. Nacional de Medellin	Colombia	Villegas	Clara	Doctor	Socio-Economics	2	Country representative – task leader WP1
U. Nacional de Medellin	Colombia	David Juan	Osorio	Doctor	Environmental Economics	2	Task leader WP2
U. Nacional de Medellin	Colombia	Lina	Berrouet	Doctor	Social sciences and participatory modelling	2	Task leader WP4
U. Nacional de Medellin	Colombia	Upegui	Alba Mery	Doctor	Social sciences	2	Task leader WP3
CIAT	Colombia	Quintero	Marcela	Team Leader	Agriculture and ecosystem services	2	Task leader WP2
CIAT	Colombia	Cruz-García	Gisella	Doctor	Participatory scenarios	2	Task leader WP3
Stockholm Environmental Institute	Sweden	Gardner	Toby	Doctor	Ecological sciences	1	Scientific advisor

(** French coordinator ; * Mexican coordinator; M.C.: Maître de Conférences; D.R.: Directeur de Recherche)

Changes with regard to the pre-proposal

A French research site has been added in order to capture the effect of environmental policies and organic agriculture in defining specific SES properties and interactions with regard to climate change vulnerability.

1. Context, positioning and objectives of the detailed proposal

Overall scientific context

Individuals, communities and sectors experience a broad array of multi-scalar and multi-temporal, social-ecological, political and economic changes and pressures to which they are exposed (Barnosky et al., 2012). Finding solutions to adapt to these changes is particularly complex in climate change vulnerable social-ecological systems experiencing rapid land use and social changes such as watersheds in periphery zones of big cities, where social and economic processes are closely intertwined by an altitudinal gradient (Burgos et al. 2015). For example, as changes in average temperatures and rain patterns are changing the distribution of suitability areas for crops, new conflicts will emerge in between the demand for new agricultural land in areas traditionally reserved for environmental conservation and water regulation services . Forests, in particular, normally present in the upper parts of the basins, play a critical role in sustaining local livelihoods and enable adaptation to climate change at the regional and global scales (Pérez-Campuzano et al., 2016). If we are to protect forests while sustaining and increasing food production and water consumption in rural-urban watersheds, we need an integrated understanding of agriculture and forests systems as for which outcomes in terms of flow of ecosystem services, management strategies and quality of life are the result of the interactions between their biophysical and social dimensions.

A highly visible conceptual tool, the Social-Ecological System framework (SES) (Ostrom, 2009), offers a potential to address complex interactions of social-ecological systems in space and time, thanks to the description of different sub-systems and its second and third level key variables. Nevertheless, its operationalization remains scarce. Ostrom (2009) first attempt to operationalize the

SES framework consisted in four subsystems: Resource Units, Resource System, Governance System and Users, which are also described as first-level dimensions whose properties are explained by a series of second-level dimensions (e.g. productivity of the resource system, economic value of the resource, strength of networks, types and degree of enforcement of rules). External to the SES are the social, economic and political settings, and other related SES, that act as external drivers of change. All four subsystems interact (named as Interactions in the original framework) in a series of specific social-ecological feedback processes that lead to the Outcomes (Enfors, 2013). In the social dimension, Outcomes respond to ecosystem management practices, economic wealth and human well-being. The trajectory of a SES is defined by a specific set of Outcomes in the ecological (ecosystem services quantity and quality) and social (management practices and humane well-being) dimensions. A shift will be detectable through the change in the level of both dimensions and will affect SES Outcomes in terms of its potential for social-ecological sustainability. This potential is defined as the likelihood that human and nonhuman components of the SESs are maintained to meet the needs of both people and nature, now and in the future (Levin and Clark, 2010).

However, while a number of studies have attempted to operationalize the different sub-systems' dimensions in quantitative indicators, further empirical research is needed in particular to describe causal mechanisms and interactions between external and internal drivers of change. For example, Bennett and Gosnell (2015) related SES second-level dimensions to the implementation characteristics of Payments for Environmental Services (PES) in the Tualatin river (US), but did not provide further quantitative investigation on their implications for the functioning of the SES. Hinkel et al. (2015), Schlüter et al. (2014) and Lescourret et al. (2015) proposed a formalization of the SES framework for forest, fisheries and agriculture systems, but remained again at the level of refining subsystems and its second-level dimensions without reaching its full quantitative operationalization. The work of Leslie et al. (2015) provides the first complete operationalization of the framework for small-scale fisheries in Baja California Sur in Mexico. They find that regions that exhibit greater potential for social-ecological sustainability in one dimension do not exhibit it in others, and highlight the need for further research on the implications of such heterogeneity for the long term maintenance of these systems. Nevertheless, Leslie et al. (2015) fails into providing a causal mechanism for these sustainability trade-offs. Overall, current research has failed to fully operationalize a theory of change for SESs. Rural-urban watersheds, where anthropogenic change occurs with increasing rapidity, complexity and uncontrollability due to social-ecological feedbacks embedded in a geographical matrix, are a privileged research natural experiment where to understand social-ecological causal mechanisms. Rural-urban watersheds are composed of a mix factors and actors organized by an altitudinal gradient, both collaborating and competing, and where a rearrangement of land uses –including further expansion of agriculture- that provide a variety ecosystem services for different actors, is driven by both markets and a mix of conservation and development policies. How this diversity of actors interacts across time and space will shape bottom-up governance structures and affect their vulnerability when facing climate change. Spatiotemporal changes in SES key variables can be defined as social-ecological trajectories. Trajectories will also be influenced by the mix of incentives and policies, by biophysical variables such as soil quality and availability of water and by the development infrastructures. SESs trajectories in rural-urban watershed can follow patterns of urban expansion, agricultural intensification, land sparing between conserved and exploited land, a highly diversified land use structure and a reorganization of the spatial distribution of agricultural crops due to changes in temperature altitudinal patterns.

In addition, policies and governance dynamics that reinforce social capital can be a source of economic and human development by enabling social-economic reciprocity and cooperation. Therefore, one of the most pressing sustainability challenges faced by these landscapes remains to be answered: What type of governance dynamics –e.g. polycentric vs centralised- can ensure that development benefits more vulnerable communities while allowing conserving critical ecosystem for watershed services such as forests? How might policy goals and outcomes in a rural-urban watershed need to be different from those in regions that do not have such degree of social-ecological vulnerability under climate change stressors? Rural-urban watersheds trajectories' are in particular driven by a combination of urban-driven markets and demand of goods and services coming from rural agricultural and natural areas. While rural-watersheds in industrialised countries are experiencing new policies that prioritize important investments in green infrastructure for improving water regulation services –e.g. cases of Catskill and Munich (Grolleau and McCann 2012)- and a transition towards agro-ecology, rural-watersheds of emergent and poor countries have large preserved forested areas threatened a non-coordinated demand of diverse services –demand for urban spaces, water regulation and food- that are in competition (Puig 2016). Moreover, climate change in temperature and rain temporal and spatial patterns will add a complexity factor to assure the provision of water and food to urban centres (FAO 2012). Very little scientific work has specifically focused on analysing such relationships in terms of a social-ecological theory of change to face climate change risks and ensure sustainable SESs. In particular studies have failed to explain the role of governance dynamics – type of organizations, types of rules, spatial organization of networks- into helping to adapt to climate change exposure. We need to understand if the matching of ecological and institutional scale increases the likelihood for sustainable social-ecological trajectories to happen. Likewise, further research is needed to identify what quantitative indicators define SESs' trajectories and what levels enable social-ecological sustainability in particular in term of decreased vulnerability to climate change.

To addresses this research objectives the project needs to cope with social-ecological heterogeneity in terms of forms of governance, forest ecosystems, agricultural management systems, water related organizations and infrastructure and climate change risks. Types of urban attractors in terms of demand for rural goods and services play also a fundamental role. To this end, TRASSE project proposes an approach based on the comparison of rural-urban watersheds SES in Colombia, Mexico and France. We believe the very distinct and complementary national context – with Colombia facing a deep rearrangement of watershed governance processes, Mexico undergoing the conformation of watershed governance structures and France standing out for its investments in green and blue infrastructure and agro-ecological agriculture- associated with the different institutional pathways of these countries will help us identify the social-ecological trajectories and its implications in terms of advancing toward a generic theory of change for the sustainability of SESs to cope with climate change vulnerability.

Scientific objectives. Scientific and technical barriers to be overcome.

The overall scientific objective of the project (**Objective 1**) is **to operationalize a theory of change for the sustainability of Social-Ecological Systems in rural-urban tropical and Mediterranean watersheds and their vulnerability in the context of Climate Change.** This overall objective will be addressed through five secondary objectives:
Objective 2: Provide an operationalization of social-ecological rural-urban watershed systems to compare the interactions of main variables and feedbacks in order to link them to social-ecological vulnerability analysis (RQ1 and RQ2).
Objective 3: Identify the role of multi-level governance in shaping over time the social capital and the sustainability potential of watersheds SES and analyse non-linear changes related to new policies and historical changes. (RQ1, RQ2 and RQ3).
Objective 4: Explore spatiotemporal changes in land use and ecosystem services to identify transitions (RQ3 and RQ4).
Objective 4: Determine and compare social-ecological trajectories in the three watersheds and how they relate to increased or decreased levels of vulnerability under climate change. (RQ4).
Objective 5: Identify which research boundary objects allow the co-construction of interdisciplinary scientific knowledge (RQ5).

These objectives will be developed through the investigation of the following research questions:
RQ1: **What dominant theories of change explain the social-ecological trajectories and sustainability outcomes of rural-urban watersheds systems to date?**
RQ2: Do SESs with governance structures matching environmental problems –polycentric vs centralised- exhibit greater social-ecological sustainability?
RQ3: How do ecosystem services trajectories affect the vulnerability and resilience of rural-urban watersheds?

RQ4: Is there a spatial and temporal variation of social-ecological sustainability that can be explained by different trajectories in ecosystem services in combination of conservation and development policies and cooperative governance?
RQ5: What research activities are needed to enhance interdisciplinary thinking in a team of multidisciplinary scientists?

The main scientific challenge of the project will be to develop a quantitative framework based on measurable indicators of both qualitative and quantitative information, ecological and social variables. Once indicators are defined, they will be documented using a combination of field interviews, questionnaires, use of secondary datasets (e.g. national statistics) and earth satellite image analysis. Technically, it implies the spatially explicit combination of qualitative and quantitative information on a temporal basis. This will be achieved through the combination of social-ecological qualitative and quantitative information on spatial and temporal basis, using innovative modelling techniques (Vallet et al. 2016). In particular we will use the Ocelet software (http://ocelet.fr/ocws/index.php?lang=fr) developed by CIRAD (Degenne and Lo Seen, 2016), which allows to model spatiotemporal changes in geographical landscapes. It is characterised by the use of interaction graphs (graphs with interaction functions on their edges) to represent the system as composed of social-ecological processes, each involving several entities (e.g. communities, private farmers, cooperatives, institutions) distributed in space that are in interaction with each other.

Scientific ambition and innovation
The project ambitions to understand which trajectories have evolved towards social-ecological sustainability in terms of vulnerability under climate change scenarios and which have not. Such a scientific result will allow positing new generalizations over generic causal mechanisms and interactions between drivers of change in order to advance towards a theory of change for the sustainability of SESs, an understudied research issue when dealing with complex human-nature systems. Finally, we will explore how TRASSE scientists' understanding of sustainability problems and solutions evolve along the project by assessing the role of boundary objects into fostering the internalization of concepts and semantics coming from the SES framework as well as the production of new interdisciplinary objects (e.g. maps, reports, manuscripts, research protocols). This research activity is a rarely implemented and an important one for improving transdisciplinary thinking in sustainability research projects (Clark et al., 2011).

Expected results
In terms of finalized products, the project will produce the following quantitative and qualitative products:
Qualitative products:

- A generic theory of change for the sustainability of SESs in rural-urban watershed
- Analysis of the role of governance based on the study of the evolution of institutions and networks of action over time (figures showing multi-level governance architecture);
- Analysis of the social-ecological history in the three landscapes with time arrows synthesizing their evolution over time and main events.

Quantitative products:

- Formalization and operationalization of SES in rural-urban watersheds, through the implementation of quantitative indicators describing the four subsystems and its outcomes;
- Measurement of trajectories over time (tables, figures);
- Spatiotemporal modelling of SES at the watershed level using Ocelet software.

State of the art and partners' contributions to it – Preliminary results if applicable
Initial efforts to understand the functioning of ecological and social systems as a coupled system emerged as a response progressing global degradation of natural resources (Berkes and Folke, 1998). A number of different conceptual frameworks have been developed to frame and systematize interactions of the social and ecological systems from different epistemological angles. Since the development of the early frameworks on DPSIR indicators (Driving forces-Pressures-States-Impacts-Responses) developed by the European Environmental Agency in 1999 (Bosch et al., 1999) and the

sustainable livelihoods approach (Ashley and Carney, 1999) that put an emphasis on very different scales –at system state for the former and at household level for the latter-, an number of frameworks have tried to capture the intertwined and multi-scaled nature of social and ecological systems. In particular, the ecosystem services framework, the capital asset framework (Green and Haines, 2008) and the management and transition framework (Pahl-Wostl and Kranz, 2010), have proposed more integrative approaches to explain intertwined social and ecological dynamics. Anderies el al. (2004) provided the first conceptual framework to study SESs in which subsystems where named 'entities[1]'. This framework gave a particular relevance to the role played by infrastructure and institutions (Ostrom, 2009). However, these second-level properties (or dimensions) have proved difficult to decline into functional indicators at case study level. Instead, the majority of studies have focused on refining the conceptual framework (Lescourret et al., 2015) or on applications to particular case studies (Hinkel et al., 2015). Two studies have provided an insightful operationalization of the SES framework: Enfors (2013) combined the SES framework to resilience theory to study trajectories of small-scale water system innovations in order to understand which SES variables (described as key system variables in her publication) enable changes in feedback loops and shifts in the trajectory. Leslie et al. (2015) pushed forward the operationalization of the SES framework for small-scale fisheries by providing a quantitative framing of the contribution of different indicators to the four SES dimensions (Fig 1).

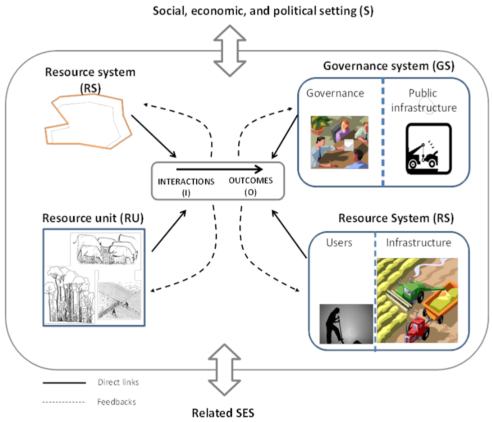

Figure 1. SES conceptual framework for forest-agriculture SES (adapted from Leslie et al., 2015).

The second challenge corresponds to their geographical delimitation. Although SESs can have multi-layered spatial architecture, it is also necessary to delineate their spatial boundaries in order to answer to a specific research question (Hinkel et al., 2015). Basurto et al. (2013) groups small scale fisheries using key ecological –coastline morphology and fish species- and socio-economic variables –migration, marine resource use and concentrations and movement of fishers and fisheries catches.Setting those limits is a challenge that still needs further research. Finally, trajectories can be described as a specific set of qualities of ecosystem services and socio-economic dimensions that are maintained in time by specific social–ecological feedbacks (Folke et al., 2010). If the level of change is important enough to alter the main feedbacks, the system will change its trajectory of development. This can lead to a sudden change in system feedbacks, and consequently an abrupt shift between trajectories. Trajectories of SESs are difficult to study and evidence is scarce. Enfors (2013) is one of the rare studies providing a qualitative modelling of what key system variables define the trajectories of small scale agro-ecosystems in Tanzania and how significant changes in these variables alter the flow of ecosystem services, therefore provoking a change in the trajectory –described as a regime shift.

<u>Partners' contribution to the state of the art:</u>
<u>Dr. Driss Ezzine-de-Blas</u> (CIRAD, French coordinator) has analyzed development strategies of small-scale farmers in the Tropical forest landscapes for more than ten years. In particular, his research has focused on understanding the causal mechanisms behind the impacts of conservation and development

[1] These four entities are: Resource, resource users, public infrastructure and public infrastructure providers.

policies (Ezzine-de-Blas et al., 2016). Dr. M. Perevochtchikova (COLMEX, Mexican coordinator) work in operationalizing the SES for forest peri-urban communities in Mexico have highlighted the need to consider social and ecological dimensions at different scales (Perevochtchikova 2015; Perevochtchikova et al., 2015). Dr. Sophie Avila (UNAM-IIEC) has been conducting extensive resilience analysis in mangrove fishing communities of Oaxaca. (Avila-Foucat, 2012). Dr. Toby Gardner (Stockholm Environmental Institute) is also co-coordinator of the Sustainable Amazonian Network (http://www.redeamazoniasustentavel.org/). Dr. Johan Ozswald (Université de Rennes) has showed the existence of tipping points in the quality of biodiversity as a function to land use management in particular when associated to monoculture extensive activities (Vallet et al. 2016). Dr. Bruno Locatelli research on ecosystem services trajectories has provided strategic management principles for achieving sustainable management of tropical SES landscape level (Locatelli et al., 2017). Clara Inés Villegas-Palacio (Universidad Nacional de Colombia, sede Medellin) has worked in the valuation of ecosystem services in rural-urban watersheds on Colombia, and how its value could be affected by climate change (Villegas-Palacio et al., 2016).

Social, economic, regulative, environmental and other related issues and how the project relates to these issues

Different environmental and rural development (social and productive) policies are at work in the three landscapes where the project will conduct fieldwork. In Mexico, environmental policies such as payments for forest and biodiversity conservation programs, forest management (Programa Nacional Forestal-PRONAFOR), biosphere reserves and integrated conservation and development (Programa de Conservación para el Desarrollo Sostenible-PROCODES) are confronted in the same territory to development programs. Rural development policies are represented by cattle productive incentives (Programa de Producción Pecuaria Sustentable y Ordenamiento Ganadero y Apícola–PROGAN), subsidies for subsistence agriculture (Programa de Apoyos Directos al Campo–PROCAMPO) and poverty alleviation programs (Programa de Inclusión Social–PROSPERA). In Colombia, the National Development Plan 2014-2018, 'Everyone for a new country' supports agricultural and productive practices as well as the conservation of strategic ecosystems (e.g. *paramos*) through a territorial planning of activities. It coordinates with the National Policy of Integral Management of Biodiversity and Ecosystem Services which details the protection needs of vulnerable areas (around 900.000 hectares in the department of Boyacá). Contrary to the Mexican case where conservation and development policies are centralized, Colombia is characterized by a strong level of decentralization in the specification of operational rules for rural development and conservation policies. Under national and European policies, France has proved to support an active commitment towards ensuring a better connectivity of natural ecosystems and rivers. Some examples of such dynamism are reflected by the Grenelle law launched in 2007 and Natura 2000 European network of protected areas. Moreover, France has experienced a maintained increase in both offer and demand of agro-ecological production which is getting translated in an expansion of organic agriculture and a public support for an agro-ecological transition. Such a mix of conservation and development policies in the three regions where the project will work will be studied in terms of their historical emergence, evolution and zone of influence. This will allow characterizing these policies over time and integrating them in the quantitative analysis of social-ecological trajectories.

How the project relates with regard to competing/complementary/previous scientific projects
With respect to previous ANR funded projects that are linked to the scientific objectives of TRASSE and in which scientists participated, we can mentions three project: AMAZ and PESMIX under the former SYSTERRA call and COFORTIPS, and ongoing Biodiversa ERA-NET project. The detailed results of these three projects are summarized below:

DURAMAZ phase 1 research project aimed at providing a better understanding of tarde-offs between social and ecological impacts across the Amazon region, using a historical and earth-satellite analysis approach (Le Tourneau et al., 2013). DURAMAZ phase 2 has built on the previous results in order to analyse the interactions between indicators to build a sustainability theory on Amazon social-ecosystems.

AMAZ (Gestion durable des services écosystémiques en Amazonie) aim was to study the ecosystem services of agro-forestry-pastoral landscapes in the Amazon through analysis of socioeconomic determinants and predictive simulation scenarios using multi-agent modelling. The project found the existence of tipping points of biodiversity presence and quality as a function of the degree of agricultural intensification. A sharp decrease in the level of specific biological diversity happens when the degree of agricultural intensification reaches in between 0,4 to 0,5 (i.e. 40% to 50% of the total farm converted to agricultural production) (Ozswald, 2013).
PESMIX (Paiements pour services environnementaux : nouvelle panacée ou auxiliaire pour gérer les territoires ?) analysed the impact of the program of payments for hydrological services in Mexico in the land use and forest and agricultural management techniques and governance in forest communities of Yucatan and Chiapas (http://pesmix.cirad.fr/). PESMIX found that its implementation had direct impacts in the agricultural practices and in governance dynamics. In terms of agricultural practices it has strengthened the use of pesticides and fertilizers for maize, and cattle production at smallholder scale (Ezzine de Blas et al., 2015).

2. Scientific and technical program, project organization

Scientific program and justification of working packages

The project will be organised in 5 working packages:

Working package 1. Operationalization of SESs and links with vulnerability framework. **Leaders:** Maria Perevochtchikova (COLMEX-CEDUA) & Driss Ezzine-de-Blas (CIRAD-FORETS). This working package will consist in:

- Spatial localization and delineation of social-ecological subsystems in terms of resource (riparian, agricultural, forest etc.) and actor systems;
- Definition of second, third and fourth level SES key variables.
- Identification of the links between SES key variables and climate change vulnerability.

Working package 2. Tracing the social-ecological history of the landscape: A historical analysis of productive systems, ecological disturbances, governance dynamics and climate change vulnerability. **Leaders:** Jean-François Le Coq (CIRAD-ARTDEV) & Sophie Ávila-Foucat (UNAM-IIEC). This working package will consist in:

- Bibliographic review of the process of regional integration (evolution of land uses and productive systems) and main ecological disturbances;
- Mapping and network analysis of governance dynamics and institutions (cooperatives, farmers' associations, environmental associations, consumer groups);
- Chronology and mapping of policies and social-ecological disruptive/transformative points.

Working package 3. Analysis of ecosystem services transitions. **Leaders:** Bruno Locatelli (CIRAD–B&SEF) & Johan Ozswald (Université de Rennes) This working package will consist in:

- Definition of ecosystem services based on land uses and secondary data;
- Land cover change analysis;
- Analysis of ecosystem services transitions.

Working Package 4. Elaboration of spatiotemporal trajectories using Ocelet software. **Leaders:** Valéry Gond (CIRAD–B&SEF) & Lucia Almeida-Leñeiro (UNAM-Facultad de Ciencias). This working package will consist in:

- Spatial definition of SESs entities, interactions and outcomes in Ocelet programming language;
- Retrospective and prospective modelling of SES trajectories;
- Comparison of results and definition of a social-ecological theory of change.

Working package 5. Coordination and co-construction of interdisciplinary knowledge. **Leaders**: Maria Perevochtchikova (COLMEX-CEDUA) & Driss Ezzine-de-Blas (CIRAD). This working package will consist in:

- Ensuring kick-off scientific workshop;
- Conduct follow-up evaluation meetings;
- Organise final international conference and dissemination of results;

- Monitor the evolution of transdisciplinary thinking and research among the scientists involved in the project.

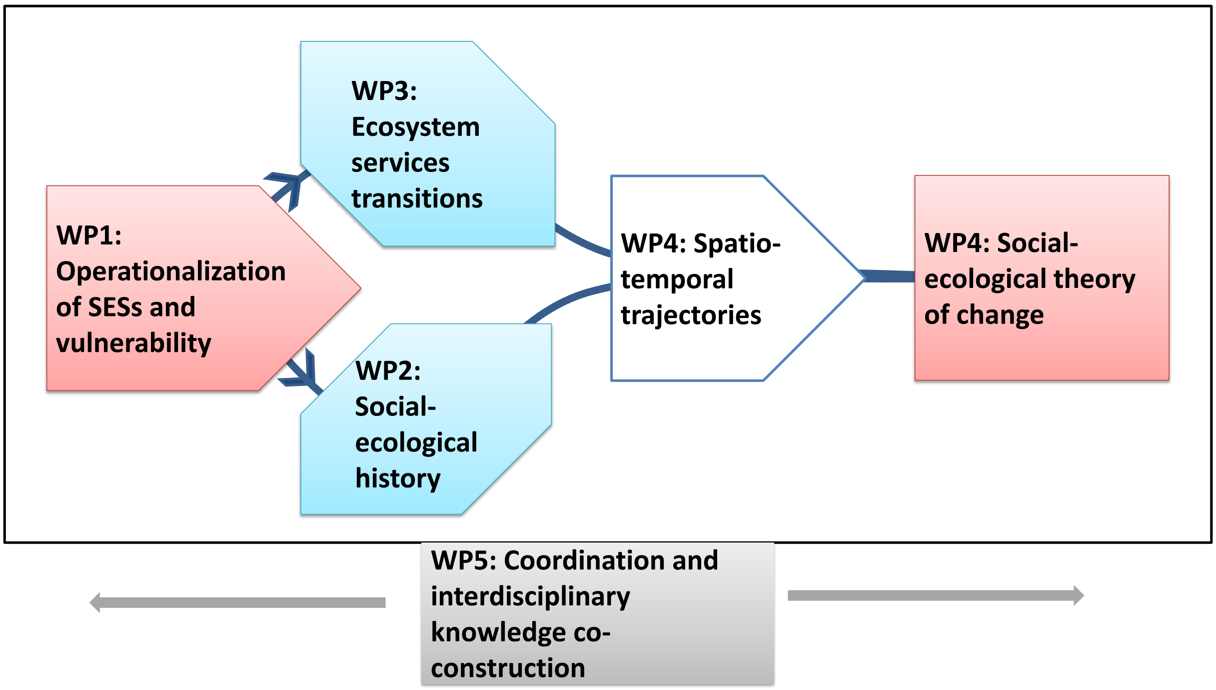

Figure 2. Project scientific organization.

Given the complexity of producing time series of spatially explicit indicators we will concentrate into feasible but theoretically grounded indicators to be documented using field interviews, secondary data and satellite images. No questionnaires will be implemented at house-hold level. Questionnaires to complement socio-economic data on secondary variables and key indicators on governance and management outcomes will be implemented at the first-level of tenure unit, i.e. community level, large private property, settlements or farmer cooperatives. Given that the ambition of the project is also to support collaborative thinking and landscape adaptive management activities, the governance of the project will be assured by two project coordinators in tight coordination with working package leaders and country representatives (Fig 3).

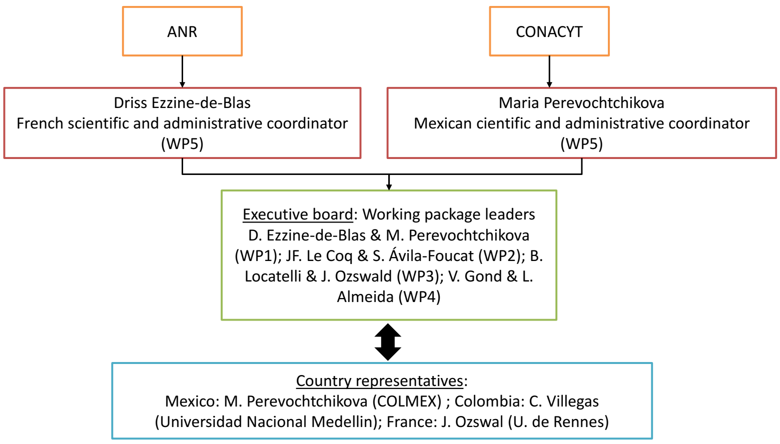

Fig 3. Project overall organization and governance.

The governance structure of the project will allow to:

- Assure strong scientific leadership from working package leaders;

- Attune methodologies to each case study specificity while keeping the needed homogeneity between scientific protocols for answering research questions based on comparative analyses;
- Foster interactions between country leaders and research teams in order to learn and exchange from different scientific expertise;
- Coordinate scientific and administrative reports for the Mexican and French coordinators.

Moreover, an executive board composed by working package leaders will make sure that the research questions are translated into the appropriate field protocols. The WP will be chaired by two coordinators – one French and one Mexican- assisted by a leader for each individual WP task. The WP coordinators are responsible for the overall follow-up and for ensuring efficient communication in their respective working package. They will also ensure that the WP tasks advance as planned. In particular, working package coordinators will be in charge of assuring the following administrative and scientific responsibilities:

Administrative responsibilities:
- Submit to project coordinators a mid-term project and final project report on their working package;
- Submit to the project coordinators a follow up of financial needs and allocation in between tasks;
- Monitor tasks' advancement and deliverables;
- Identify potential risks and notify any difficulty in the advancement of the tasks.

Scientific responsibilities:
- Propose a methodology for the entire WP and participate into declining it for each task with task leaders and national representatives, including general theoretic foundation, empiric research methods and field protocols;
- Monitor and ensure the advance of research protocols in each task;
- Ensure efficient communication and concatenation of tasks;
- Participate in the executive board scientific decisions.

The executive board will meet physically each year and via teleconference when necessary. The project will start with an executive board meeting combined with a methodological meeting for WP1 and WP2 at COLMEX (Mexico City, Mexico). The executive board meeting will be repeated once a year to present working package advances and to promote scientific synergies between research activities. The venue of the executive board meetings will alternate in between CIRAD (Montpellier, France) and COLMEX (Mexico City, Mexico) (Table 3). Each working package will start with a methodological meeting during the executive board meetings.

Month	Meeting	Participants	Duration (days)	Objectives	Venue
0	Project kick off meeting: Working package methodological meeting (WP1 & WP2) and executive board meeting	15	4	Fine tune project scientific chronogram, means, and administrative procedures. Initial research protocols and field logistics for WP1 and WP2	COLMEX (Mexico City, Mexico)
6	Working package team briefing	5	1	Reporting on progress. Co-design research protocols and field logistics	Teleconference
6	Training: Ocelet	5	10	Learn to use Ocelet software and become an autonomous programmer	CIRAD (Montpellier, France)
12	Executive board and working package methodological meeting (WP3)	8	4	Analysis of first results – Methodological meeting WP3	COLMEX (Mexico City, Mexico)
18	Working package team briefing	5	1	Reporting on progress. Co-design research protocols and field logistics	Teleconference
24	Synthesis WP1, WP2 and WP3 and working package methodological meeting (WP4)	15	4	Analysis of second results	UNAL Medellin (Medellin, Colombia)
30	Working package team briefing	5	1	Reporting on progress. Design of scientific publication including special issues.	Teleconference
36	International Conference	50	3	Presentation of project results.	CIRAD (Montpellier, France)

36	National seminars	25	1	Presentation of project results in the field	Mexico City (Mexico), Bogotá (Colombia), Montpellier (France)

Table 3. Chronogram of management and methodological meetings.

Description of working packages

Working package 1. Operationalization of SESs and links with vulnerability framework.

This first working package will have the objective of operationalizing the SES in terms of its boundaries and main variables. Whereas the existing works developed by Hinkel et al. (2015), Schlüter et al. (2014) and Bennett and Gosnell (2015) have operationalized the SES at a generic level using sub-systems that represent the different landscape social-ecological entities (stream, forest agriculture, farmers etc.), we will define SES in an interlinked manner as part of larger SES or meta-SES (Fig 2). This spatialization will be done by combining homogeneous governance and biophysical criteria. In a second step, we will do a literature review to identify the 2nd and 3rd level variables. Finally, we will validate this first operationalization with two workshops. In particular, WP1 will consist on:

1.1. Spatial delineation of SESs:
  - Using existing statistics we will build a spatial explicit mapping of agricultural (type of production system and crops), poverty, biophysical (slope, land cover) and land tenure (private vs community property) indicators in order to identify homogeneous patterns. These SESs will be identified as SES 1, SES 2 and so forth (Fig 2).

1.2. Identification of 2nd and 3rd level variables and interactions:
  - Second, we will perform a literature review in order to identify 2nd and 3rd level variables and interactions that are pertinent for describing the identified SESs (See Annex 1).

1.3. Identification of the links between SES key variables and climate change vulnerability:
  - Following Bennett et al. (2016) vulnerability framework we will identify which SES key variables correspond to exposure (e.g. defined by climatic history and climate change scenarios), sensitivity and adaptation (e.g. access to human, social, physical, financial and natural assets, capacity to organize, leadership, learning and knowledge, imaginative resources and capacity to self-organize).

1.4. Validation workshops with stakeholders – Identification of local indicators of climate change:
  - In order to validate the conceptual operationalization of the rural-watershed in SESs we will conduct at least participative workshops. The workshops will gather local actors –farmers, technical intermediaries, local community leaders, local authorities- and regional and national actors in different occasions, in order to frame the discussions to the geographical scale in which actors feel more confident. We expect local actors to bring local indicators of climate change while regional and national actors will have a better understanding of the interactions, outcomes and external settings (e.g. drivers of change).

Working package 2. Tracing the social-ecological history of the landscape: A historical analysis of productive systems, ecological disturbances and governance dynamics.

The study of social-ecological rural-urban watersheds needs to be, first of all, approached from a historical perspective in order to understand the economic process of regional integration, what policies and governance institutions have shaped the territory and the main ecological disturbances that shaped their development. This working package will identify convergent and divergent changes in what have been the main productive systems, how forests have been integrated or disaggregated from productive landscapes, the investment in hydraulic facilities, the expansion of urban centers and the type and mix of conservation and development policies that have come into action. This working package will be developed through the following tasks:

2.1. Description of the process of regional integration (evolution of land uses and productive systems) and main ecological disturbances:

- First, we will perform a bibliographic review of the main phases in the expansion of the agricultural frontier, and the evolution of productive systems and agricultural management practices. Main ecological disturbances will be identified and described, such as e.g. arrival of pests, large fires, droughts, building of dams.
- The review will be enriched using a socio-economic approach based on semi-structured interviews with key stakeholders from the productive and forest conservation sectors at regional and national levels.

2.2. Chronology and mapping of conservation and development policies:
- A bibliographic review will be performed to understand what policies were put in place in the studied landscapes. These policies include green markets, integrated conservation and development projects, protected areas, agri-environmental measures etc.
- This review will be completed through interviews with local and national experts that have been involved in the implementation and study of forest conservation and development policies in the area.

2.3. Analysis of governance dynamics and mapping of institutions (cooperatives, farmers' associations, environmental associations, consumer groups).
- Tasks 2.1. and 2.2. will be completed with a sociological and institutional economics analysis specifically targeting the evolution of governance institutions in terms of cooperatives, association of farmers, researchers, technical intermediaries, community based management institutions.
- The qualitative information will mapped so to locate of the different types of institutions,. in a flow diagram showing the multi-layered governance structure of the landscape in order to explore the evolution of networks between organisations (polycentric vs monocentric governance) as a measure of social capital at the SES level.

Working package 3. Ecosystem services transitions: exploring the evolution of types of services produced by the SESs.
This working package will summarize complex spatial and temporal dynamics of land-use changes integrated with socio-institutional data (public policies and networks actors influencing the land cover dynamics – WP1 & WP2). First, we will use the Invest model (http://www.naturalcapitalproject.org/invest/) to map several types of ecosystem services indicators (climate regulation through carbon storage, water cycle regulation through infiltrability, ecosystem regulation through biodiversity populations). Second, we will use statistical methods to forecast the distribution of service indicators such as regression tree (CART algorithm) or multiple linear regressions (Vallet et al., 2016). The multi-temporal land cover mapping will be obtained from geometrically and radiometrically corrected satellite images to characterize the composition and structure dynamics of land use changes in order to capture key forest-agriculture outcomes such as the degree of agricultural intensification .

Three tasks of research are proposed:
3.1. Mapping of ecosystem services indicators:
- The mapping of climate regulation through carbon storage, water cycle regulation through infiltrability, ecosystem regulation through biodiversity populations will be done using InVest model.

3.2. Elaboration of a multi-temporal land cover analysis:
- Such a multi-temporal a land cover analysis will produce two main outcomes: a land use change map and overlapped principal component analysis of how land use has changed inside each of the governance units and of the SESs.

Working Package 4. Spatiotemporal trajectories, vulnerability implications and social-ecological theory of change for the sustainability of SES.
This WP will perform integrative tasks on a retrospective and prospective manner. First, empirical data obtained in WP2 and WP3 will be integrated to generate a first lineal semi-quantitative identification of past social-ecological trajectories. Second, in order to integrate the social and ecological results from WP2 and WP3, WP4 will perform an integrative modelling using the Ocelet

language and simulation tool. Ocelet models changes in geographical landscapes through the use of interaction graphs to represent the different sub-systems in each SES. Ocelet allows spatially locating these different sub-systems and specifying the interactions among them to make the system change through time. Modelling the past behaviour will explicit the trajectories of the SES and how they relate to the resilience of the system and to their vulnerability under climate change scenarios. Finally, we will perform prospective analysis to understand how business as usual vs best case scenarios might affect the sustainability of the whole watershed.

In particular, this working package will consist on the following tasks:
4.1. Definition of entities and model specifications.
4.2. Integration of empirical evidence and simulation of past trajectories:
- Empirical data obtained in WP2 and WP3 will be integrated to generate a first lineal semi-quantitative identification of past social-ecological trajectories;
- Simulations will be guided by the main processes and interactions identified and empirically described in the previous WPs. An example of processes will be i) the geographical distribution of plots as a means to face climatic risks, ii) the effect of fallowing practice in a spatially constrained cotton dominated landscape and iii) the consequences of reduced access to credit for farmers to buy fertilizers.
- Elaboration of prospective scenarios.

4.3. Comparison of results and description of a social-ecological theory of change for sustainable SES.
- Retrospective trajectories based on empirical evidence and prospective modelling will allow identifying pathways of change. Pathways of change will be systematised to identify which SES key variables, interactions and outcomes have been the more decisive in generating the observed changes both in terms of sustainability and degradation. This generic pathway of change will be enounced in terms of causal mechanism or theory of change.

Working Package 5. Coordination, dissemination and monitoring of transdisciplinary project thinking.
This working package will assure the scientific and administrative reporting. It will also deal with project management needs. Besides, although focusing on coordination, communication and dissemination, this working package will monitor the evolution of transdisciplinary thinking and research among the scientists involved in the project. This task will be performed using questionnaires that will be filled by project participants across the different meetings described in table 2. This questionnaire will monitor repetitive questions along the three years of the project to capture the role of reports, models, maps, and research protocols into creating a shared understanding of SES concepts. Results will be represented in the form a spider diagram showing how their comprehension of SES interactions and steps needed to study them have evolved. This analysis will make us understanding what type of research actions have contributed the most into pushing forward transdisciplinary collaborative research.

Partners' contributions:
COLMEX and UNAM will strongly contribute to the methodological development of WP1 and WP2 through synergies with their ongoing CONACYT and PAPIIT projects. In particular, they will contribute at identifying which are the main social-ecological dimensions to be monitored in terms of external stressors and relevant changes in forest-agriculture productive systems (use of pesticides, mechanization, soil protection techniques, logging), governance dynamics (e.g. consolidation and expansion of cooperatives) and particular conservation and development policies (e.g. incentives for deforestation and cattle production vs forest conservation). COLMEX-CEDUA will provide fieldwork logistics in the state of Mexico, liaise with forest communities and provide guidance to attune research protocols. National scientists at Universidad Nacional de Medellin in Medellin, Colombia will contribute to operationalize fieldwork logistics and attune research protocols with task leaders. Universidad Nacional de Medellin will contribute with their ground breaking COLCIENCIA project on social-ecological risk analysis in the rio Grande watershed. CIAT and SEI will provide methodologies to design sustainability indicators.

Methodological and technical choices:
The project will implement a combination of qualitative and quantitative research methods. This choice is needed in order to cope with the complexity of the SES framework in which dimensions that are easy to measure are mixed with more abstract or technically difficult dimensions. The sequential combination of qualitative and quantitative methods will allow dealing with the complexity of SESs functioning step by step. First, the operationalization of SESs in spatial and functional terms will reveal the underlying structure of the rural-urban watershed in terms of key variables and interactions among sub-systems and in between SESs (WP1). Once this structure is clarified we will capture on one side what are the main changes and disruptive historical moments that they have undergone in terms of policies, governance and socio-economic indicators on one side (WP2); and, on the other side, what transitions have happened in terms of ecosystem services (WP3). The integration of both data under the framework developed in WP1will allow represent those changes in a spatiotemporal manner while on the same time perform prospective scenarios to explore how vulnerable the rural-watershed SESs has or will become to climate change (WP4). Finally, the monitoring of interdisciplinary thinking will be performed with quick questionnaires during projects meetings and after research milestones are achieved. Table 3 shows the project chronogram (See Annex 1 table 2 for a breakdown of project management task leaders).

			2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
WP1	T11	Spatial delineation of SESs	Spatially explicit database			Mapping														
	T12	2nd and 3rd level variables, interactions	Litterature review		Operation alization				Matrix of indicators											
	T13	Validation workshops				Validation workshops			Reporting	Scientific paper										
WP2	T21	Regional integration and ecological disturbances						Litterature review			Fieldwork questionnaires			Reporting						
	T22	Conservation & development policies' mapping							Litterature review		Fieldwork questionnaires			Reporting						
	T23	Governance dynamics and mapping							Litterature review		Fieldwork questionnaires			Reporting	Scientific paper					
WP3	T31	Ecosystem services indicators	Analysis of satellite images and field verification											Reporting						
	T32	Multi-temporal land cover		Mapping of ecosystem services indicators										Reporting			Scientific paper			
WP4	T41	Ocelet model specifications					Ocelet training								Model specifications				Scientific paper	
	T42	Simulation of interactions															Simulations			
	T43	Prospective analysis																Simulation	Reporting	
WP5	T51	Intraproject interdisciplinary thinking assessment	Project questionn aire					Project questionn aire			Project questionn aire			Project questionn aire			Project questionnai re			Project questionn aire
	T52	Local restitutions															Local restitutions			
	T53	International conference																	International conference	

Table 3. Chronogram of tasks

<u>Motivations for three-country comparison: Mexico, Colombia and France.</u>

The evolution of rural-urban watersheds in three countries has been driven by some SES key variables in such a way that their comparison will allow capturing a large diversity of situations. **France centralised governance** during the *Trente Glorieuses* developed a top-down watershed planning both in terms of protected areas and urban and industrial development. While most forests have seen their surface expand, one of the main problems faced by water users has been quality: excess of nitrates and phosphates coming from agriculture as well as organic chemicals such as chlorinated compounds have posed a health and water use problem. Since the late 90's a progressive devolution of political power at regional level, the harmonisation with Europe in terms of protected areas networks (NATURA 2000) and water standards together with an increase number of local organisations and associations intervening in watershed decisions has created a new environment where bottom-up governance has gained strength. Finally, the increasing number of organic farms, a unique process together with few countries such as Spain, Germany, Italy and the US, has also created a new social-ecological driver in term polycentric governance, local development values and decrease water pollution from industrial chemicals. **Mexico has traditionally experienced hybrid Federal-and-State governance**, with some competencies managed at the Federal level and other at the State level. Whereas agriculture has shown diverse patterns of cattle, maize and other commercial crops, it has experienced since the late 80's a strong urban exodus. The Mexican-endemic form of local governance of *ejidos* and *communities* has been experiencing a continued disintegration and privatisation of communal lands, the majority of them under forest cover. Deforestation has not been stopped in part to wild fires, cattle expansion and illegal logging. Under the lack of interest and capacity of the federal water authorities to impose a top down organisation of watershed, the coordination of actors at the watershed level is relatively recent and follows a clearly bottom-up and polycentric governance. Some of these examples are the emergence of The Nature Conservancy water funds, local payments for environmental services schemes launched by local water enterprises and international funding from the Global Environmental Fund to coordinate land uses following a “water basin” concept. Finally, **Colombia has experienced a totally polycentric and decentralised model of watershed governance.** In part due to the geographical constraints, in part due to the lack of territorial security that has fragmented the country for more than 40 years, watershed actors have had a mainly uncoordinated model of occupation. While private farmers invested in extensive cattle, municipal water companies assured water provisioning in terms of volume and hydraulic infrastructure without a real connection with the territory. Only some recent institutional initiatives around the capital of Bogota and the city of Manizales have attempted to propose bottom-up coordinating policies –like the Procuenca project in Manizales initiated by FAO in 2007. Under the post-conflict context and the possible reorganisation of land to create peasant territories, including the political re-integration of large parts of the territory –some mountain areas, a complex social-ecological trajectory is about to begin. In particular, the way local and national governance will be able to find synergies or enter in conflict will affect the sustainability of ecosystem services –e.g. the recent opposition of the Cajamarca population to the AngloGold Ashanti gold mine[2].

Risks and solutions
Access to the field will be secured thanks to the long standing working tradition of national representatives with farmers and institutions in the landscapes where the project will work. Access to secondary information will be assured by national partners.

Quality and complementarity of the research group – Articulation and complementarity in between scientific disciplines – Ethical concerns.
The team of researchers involved in the project is grounded on the scientific and logistic needs of a transdisciplinary project. Scientifically, the involved researchers have a sound trajectory in ecological, social and economic sciences. M. Perevochtchikova, L. Almeida-Leñeiro and T. Gardner have a long standing experience into performing biodiversity and ecosystem services (water regulation and soil fertility) assessment in the tropics. JF. Le Coq and CI. Villegas are recognized researchers in the fields of community based management of natural resources and agriculture and forest governance in tropical regions. Their research includes the study of the historical evolution of rules and institutions and their multi-level alliances to manage the landscape. S. Avila experience in environmental and agricultural economics will bring to the operationalization of the SES framework for SES the needed expertise in behavioural economics. M. Perevochtchikova, D. Ezzine-de-Blas and B. Locatelli study of non-linear relationships between social and ecological processes will assure the transdisciplinary assemblage of researchers’ expertise.

Technical and scientific justification of funding needs
The expenses of TRASSE are divided in between field work expenses, trips and workshops, students and field assistants:

<u>Field work expenses:</u>
The project will conduct four different types of field work activities: Institutional economics and sociological research, questionnaires in productive units and satellite verification with GPS points, The ethnographic work required in WP2 will be accomplished with two interns supervised by one field mission per task leader. The analysis of satellite images will require a verification of GPS points. This work will be done by V. Gond and J. Ozswald with 10 days of field mission per country, with the support of national and regional teams for transport and logistic costs. Participatory scenario modelling with Ocelet will be done with an international training at CIRAD (Montpellier).

<u>Methodological workshops:</u>

[2] http://sostenibilidad.semana.com/medio-ambiente/articulo/cajamarca-le-dijo-no-a-la-mineria/37402

In order to ensure the highest level of scientific interaction and quality, each working package will host a methodological meeting at its start. This meeting will be of 2 days and will take place in Mexico City (COLMEX) or Montpellier (CIRAD) in order to ensure institutional representativeness.

Internships and research assistants:
Field work in WP1 and WP2 will be supported with field internships and field assistants in order to support interviews, perform questionnaires and systematize data. WP1 will need 2 internships per country (6 in total) and WP2 1 internship and 2 research assistants per country.

Short CV of the scientific coordinator and main partners

Driss Ezzine-de-Blas:
D. Ezzine-de-Blas is PhD in Ecological Economics and has conducted extensive research on the multidisciplinary evaluation of economic productive activities in tropical forest-agriculture landscapes. His currents interests are the impact evaluation of conservation and development policies and building evaluation methods in the broader framework of studying forest-agriculture social-ecological interactions and outcome over time.
Recent publications:
Brimont L, Ezzine-de-Blas D, Karsenty A, Tambaza F, Toulon A et al. 2015. Achieving conservation objectives along with equity principles in a context of extreme poverty and climatic risk: lessons from the Makira REDD+ project in Madagascar. Forests 6:748-768.
Maria Perevochtchikova:
M. Perevochtchikova is PhD in Geography. Her research focuses on the measurement of water regulation services in forest-agriculture areas and on the impact of socio-economic and governance factors on water regulation services.
Recent publications:
Pérez-Campuzano E, Avila Foucat VS, Perevochtchikova M. 2016. Environmental policies in the peri-urban area of Mexico City: The perceived effects of three environmental programs. Cities 50:129-136.
Sophie Ávila-Foucat:
S. Avila is PhD in Environmental Economics at the University of York, UK. Her research topics relate to the fields of ecological economics, rural diversification of income, social-ecological systems and resilience. She is currently coordinating two projects on the analysis of factor determining sustainable productive diversification in Oaxaca and the resilience of small-scale fisheries to extreme climatic events.
Recent publications:
Rodríguez-Robayo K, Avila-Foucat S, Maldonado J. 2016. Indigenous communities' perception regarding payments for environmental services program in Oaxaca Mexico. Ecosystem Services.17:163–171
Bruno Locatelli:
B. Locatelli is PhD in Ecology and Research Director since 2010. His research focuses on climate change adaptation and the spatiotemporal transition in ecosystem services. He has conducted extensive research in Asia, Africa and Latin America.
Recent publications:
Locatelli B., Lavorel S., Sloan S., Tappeiner U., Geneletti D., 2017. Archetypes of trajectories of ecosystem services in mountains. Frontiers in Ecology and the Environment doi:10.1002/fee.1470
V. Gond:
V. Gond in PhD in Geography and Research Director since 2013. His research focuses on the measurement of forest ecosystem functional characteristics through satellite imaging. He has conducted extensive field work in the Congo Basin and the Brazilian Amazon.
Recent publications:
Billard C, Gond V, Oszwald J, Arnaud de Sartre X, Pokorny B. 2014. Smallholders' agricultural practices trajectories in Amazonia, Bois et Forêts des Tropiques 319: 53-64.
Johan Ozswald:
J. Ozswald holds a PhD in Geography and his research focuses in the analysis of spatiotemporal data in forest-agriculture landscapes.

Recent publications:
Vallet A, Locatelli B, Levrel H, Brenes-Perez C, Oszwald J et al. 2016. Dynamics of Ecosystem Services during Forest Transitions in Reventazon, Costa Rica. PLoS One. 8 :11(7):e0158615.
Jean Francois Le Coq:
JF Le Coq is PhD in Agronomics. His research focuses on the study of governance dynamics, rules and multi-actor alliances for the implementation of conservation and development policies in the rural areas of tropical Latin America.
Recent publications:
Le Coq JF, Froger G, Pesche D, Legrand T, Saenz F. 2015. Understanding the governance of the Payment for Environmental Services Programme in Costa Rica: A policy process perspective. Ecosystem Services 16: 253-265.
Clara Inés Villegas
Clara Villegas-Palacio holds a PhD in Economics. Her research focuses on policy instruments for environmental management, integrated valuation of environmental quality and vulnerability of socio-ecological systems.
Recent Publications:
Villegas-Palacio, C., Berrouet, L., López, C., Ruiz, A., Upegui, A. 2016. Lessons from Integral valuation of Ecosystem Services: Three case studies of ecological, socio-cultural and economic valuation. Ecosystem Services 22: 297-308.
Juan Camilo Villegas
Juan C, Villegas holds a Phd in Natural Resources. His research focuses on the interactions between ecosystems and the hydrological cycle (including atmospheric, surface and subsurface components) and the effect of ecosystem disturbance on these interactions and associated ecosystem services.
Recent Publications:
Suescun D, Villegas JC, León JD, Flórez CP, Garcia-Leoz V, Correa-Londoño GA. 2017. Vegetation cover and rainfall seasonality impact nutrient loss via runoff and erosion in the Colombian Andes. Regional Environmental Change 17(3): 827-839
Lucia Almeida-Leñeiro:
L. Almeida-Leñeiro holds a PhD in Ecology. Her central field research has focused on ecosystem services, conservation, vegetation science, paleoecology and environmental education.
Recent publications:
Figueroa F, Caro-Borrero A, Revollo-Fernández D, Merino L, Almeida-Leñero L, et al. 2016. “I like to conserve the forest, but I also like the cash”: Socioeconomic factors influencing the motivation to be engaged in the Mexican Payment for Environmental Services Programme. Journal of Forest Economics 22: 36–51.
Marcela Quintero:
M. Quintero has extensive experience the analysis of water-related environmental services and land use alternatives. At present, she is the leader of the Ecosystem Services Area of CIAT and leads diverse projects in Latin America related to sustainable land use options in forest-agriculture areas.
Recent publications:
Castro A, Mertz O, Quintero M. 2016. Propensity of farmers to conserve forest within REDD + projects in areas affected by armed-conflict. Forest Policy and Economics 66:22-30.

3. Project impact, strategy of promotion, protection and utilization of the results

The project will have an impact at the scientific, policy making and socio-economic levels. At the sscientific level we expect the project to contribute to ongoing debate on how to achieve sustainability in human-nature coupled systems. By establishing a theory of change the project will allow to specific the causal pathways that complex systems can follow at the landscape scale. This will influence policy-making by increasing awareness on what strategies and policies are needed or to be maintained at the local and regional levels. Cross-learning in between research sites will be useful in opening new discussion fora in between countries’ technicians. At the socio-economic level the project ambitions that technicians and organizations will reflect about how to use public and private investments in a more efficient manner, not only in monetary terms but for coping with climate change risks. For the promotion and dissemination of the results we will use a variety of means. First, the project team will communicate with dissemination structures of participating institutions to spread publications, methodologies and scientific events. CIRAD will also produce a project web page. Two newsletters per year will be produced using the project logo to inform about project activities and other scientific events of relevance to the project (interviews, book reviews). A final conference will be held at the endo of the project in Montpellier, backed with smaller national one-day seminar and local restitutions with government institutions and other concerned stakeholders. We will also restitute the project results with local actors including communities, farmers' associations and other relevant actors.

Benefits for the French scientific cooperation
Given the international French-Mexican and interregional Mexico-Colombia-French partnership, the project will engage in a fruitful bilateral and regional scientific cooperation in order to create long term scientific networks involving scientists and research institutions. In particular, we also expect the Ocelet software to gain international recognition and widely used modelling software.

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