Original research

Aligning Socio-economic Field Laboratories and Agent Based Models assessing local climate change adaptation measures of Andean farmers

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Abstract

The increase in extreme weather events is a major consequence of climate change in tropical mountain ranges like the Andes of Peru. The impact on farming households is of growing interest since adaptation and mitigation strategies are required to keep race with environmental conditions and to prevent people from increasing poverty. In this regard it becomes more and more obvious that a bottom-up approach incorporating the local socio-economic processes and their interplay is needed. Socio-economic field laboratories are used to understand such processes on site. This integrates multi-disciplinary and participatory analyses of production and its relationship with biophysical and socio-economic determinants. Farmers react individually based on their experiences, financial situation, labor conditions, or attitude among others. In this regard socio-economic field laboratories also serve to develop and test scenarios about development paths, which involve the combination of both, local and scientific knowledge. For a comprehensive understanding of the multitude of interactions the agent-based modeling framework MPMAS (Mathematical Programming-based Multi-Agent System) is applied. In combination with continued ground-truthing, the model is used to gain insights into the functioning of the complex social system and to forecast its development in the near future. The assessment of the effect of humans' behavior in changing environmental conditions including the comparison of different sites, transforms the model to a communication tool bridging the gap between adaptation policies and local realities.

Keywords

adaptation strategies; Andean livelihood; agent-based modeling; MPMAS; climate change; extreme weather events; participation

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1. Introduction

Climate change in high elevation tropical mountain ranges, like the Andes, is not well represented in recent global circulation models. Local climate models show increased warming with a more distinct increase in temperature at higher elevations (Solman et al., 2008; Urrutia and Vuille, 2009). The tropical Andes are characterized by the high diversity of their ecosystems. The consequences of a changing climate are of increasing concern, due to the effects that alterations within those ecosystems will have on human population, directly dependent on the services they provide (Vuille et al., 2008). The retreat of glaciers and increased frequency of extreme weather events directly affects biodiversity as well as crops and livestock (Vuille et al., 2003). Large parts of the Andean region are inhabited by rural population dependent on subsistence agriculture. At the same time these are areas with a social vulnerability that increases constantly due to degradation of the ecosystem caused by social and climatic change. Traditional inhabitants of the tropical Andean region have experience in coping with extreme daily temperatures, unpredictable weather events, and a diversity of environmental conditions scattered across the elevations. Therefore locals are aware of the recurrent diversity of climate related impacts and its consequences. Hence, smallholders are applying traditional strategies in a combination of homegrown experimentation and scientific know-how to adapt to climate change (Salick and Ross, 2009). Nonetheless, climate change, functioning as an additional driver of ecosystem change and cause of shifts of resource use, brings another dimension. In addition, external determinants such as access to infrastructure, institutional support and market conditions constrain farmers' capacity of response. In the end the effects of a rapidly changing climate could jeopardize tropical Andean ecosystems and their capacity to provide a number of ecosystem services (Anderson et al., 2011). The effects of anthropogenic climate changes are likely

to be of greater magnitude, and might be experienced sooner in the Andes, than in other parts of the globe (Rosenzweig et al., 2007). It will have lasting implications especially for the livelihoods of the already vulnerable rural communities dependent on mountainous ecosystems due to the impact on water availability, and other phenomena like emerging of new pathogens and diseases (Gentle and Maraseni, 2012; Morton, 2007; Nath and Behera, 2011).

Understanding the origin of their vulnerability and the adaptations to such changes is among the most important focuses of research into climate change impacts and vulnerability, since it provides essential knowledge for developing and transferring strategies towards a sustainable management in agriculture and agroforestry (Boomiraj et al., 2010; Howden et al., 2007; Morton, 2007; Pretzsch, 2005). However, so far there still is a lack of information about the related local knowledge, behavior and action. Therefore, a comparative assessment is needed, especially in regions with high impact of extreme climate conditions (Chhatre and Agrawal, 2009). The endogenously determined strategies, which are based on the experience of the famers, are to be complemented by knowledge and experiences coming from outside farm-household systems and communities. In a collaborative way, this latter exogenous knowledge is to be placed at the disposal of local actors. Thus a participative network on climate change contributes to bridge the gap between the global discourse on climate change and local action (Bidwell et al., 2013). The necessary network approach leads to a far reaching involvement of the local actors.

One of the main challenges lies in completely capturing the systemic complexity of real-world elements of livelihoods, as well as the amplitude of cross-linkages and feedbacks existing within such livelihood systems, all embedded in the high ecological and climate variability that characterizes the Andes and their external social, economic and political determinants. Within the available pool of modeling methods, Agent Based Models (ABM) have gained popularity for assessing, ex ante, the impact of climate change on agricultural systems (Gilbert, 2008; Wang et al., 2010). ABM allow for multi-level representation and analysis of agricultural systems ranging from crop level, to farm plot, household, community up to regional levels (Schreinemachers and Berger, 2011).

The urgency of climate change requires innovative strategies in integrated research and consecutive policy and action (Vermeulen et al., 2012). The network-project (International Network on Climate Change – INCA) and its first outcomes described here, aims to develop and transfer strategies towards a sustainable management in smallholder agriculture and agroforestry under a changing climate (Boomiraj et al., 2010; Howden et al., 2007). The main objectives hereby are (i) To conduct an analysis of the biophysical and socio-economic factors that influence livelihood strategies of traditional Andean farmers and to study how these systems are being affected by climate change; (ii) To compare case study outcomes in order to generate and typify key indicators for livelihood
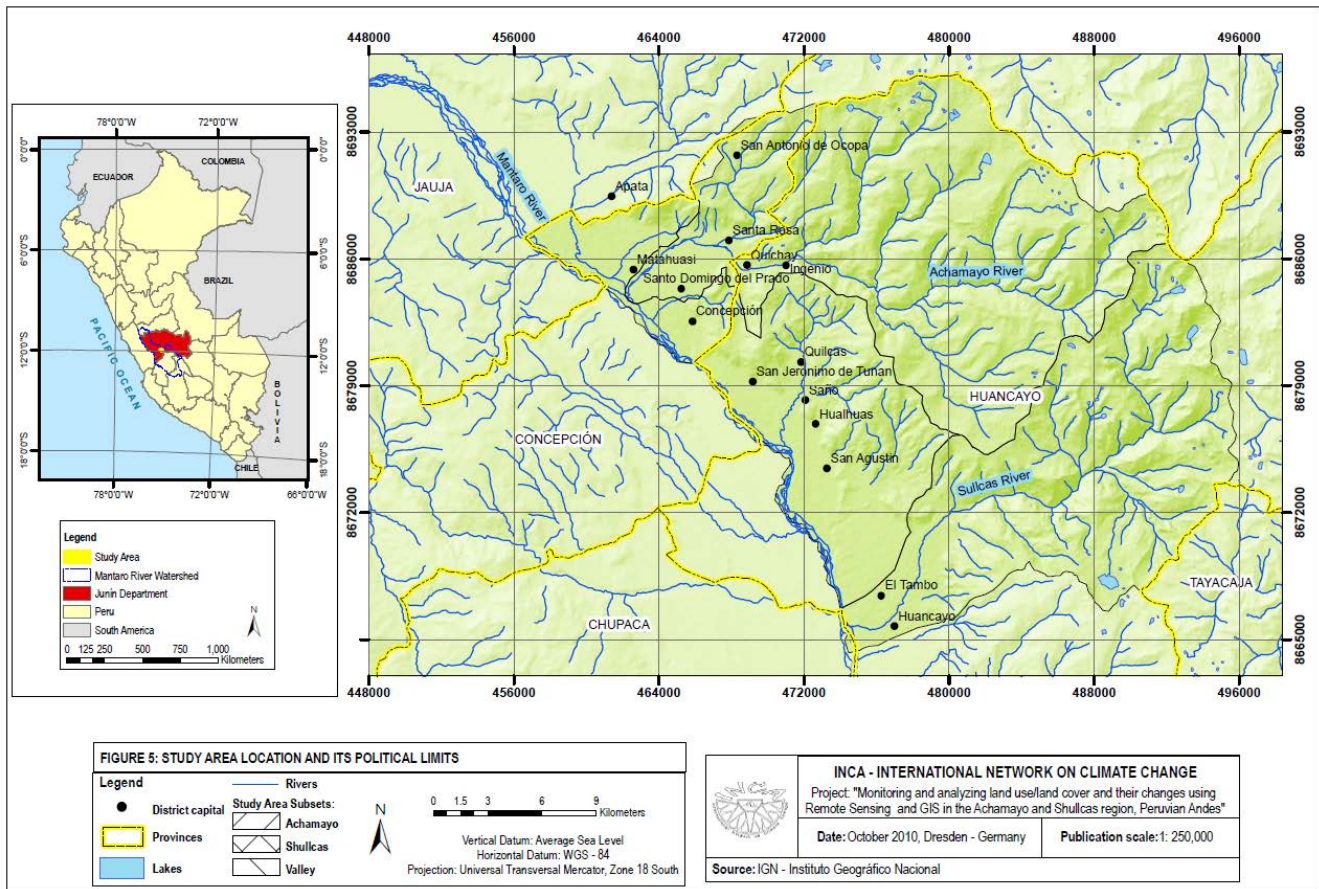
Figure 1. Study area and adjacent regions in the eastern slope of the central Andes in Peru (Source: Instituto Geográfico Nacional in Drechsel (2013))

strategies in the tropical Andean region and to comparatively assess trade-offs between options either enhancing food and income functions (adaptation strategies) or enhancing ecosystem functions (mitigation strategies); (iii) To elaborate models for the simulation and planning of successful interventions.

This paper provides an overview on the conceptual approach of the network and exemplifies its functioning with preliminary insights from the ongoing work in one of the study areas. The project concept that will be introduced on the following might work as a model for similar approaches in different regions or as baseline for continuative initiatives.

2. Study Area

2.1 Location

The Achamayo watershed is part of the Mantaro river basin, which encompasses an area of approximately 34,550 km^2 in the eastern slope of central Andes in Peru (Figure 1). Altitude ranges dramatically in the area from approximately 3,100m asl to 5,500m asl. The lower altitude is located in the western part of the study area by the Mantaro River. The study area, politically located in the Province of Concepción, Department of Junin, is a focus area of Peru's approach in achieving mul-

tidisciplinary regional cooperation for integrated assessment of climate change (Lagos, 2007). It comprises of communities with strong indigenous culture. The typical farming system is the High Altitude Mixed Farming System. There is a high variety of crops cultivated in the area: maize (*Zea* spp), wheat (*Triticum* spp), potatoes (*Solanum* spp), ulluco (*Ullucus tuberosus*), fava bean (*Vicia faba*), peas (*Pisum sativum*), vegetables and some fruit trees are among the most common products. The communities La Libertad, San Pedro, San Antonio de Ocopa and Santiago de Marcatuna were included in the study.

2.2 Climate

In the area, the rainfall reaches its highest values between January and March and the lowest in June and July. However, the amount of rain is not homogeneous. In the northern and southern-west region the highest values are 1,000 mm/year whereas in the eastern region (tropical forest areas) rainfall can reach 1,600 mm/year. The driest areas are located in the center-south (500 mm/year) (IGP, 2005). The mean annual temperature differs between 4°C in high altitudes and 8-10°C in the Mantaro valley. Fluctuations between day and night temperatures are high and can reach a maximum up to
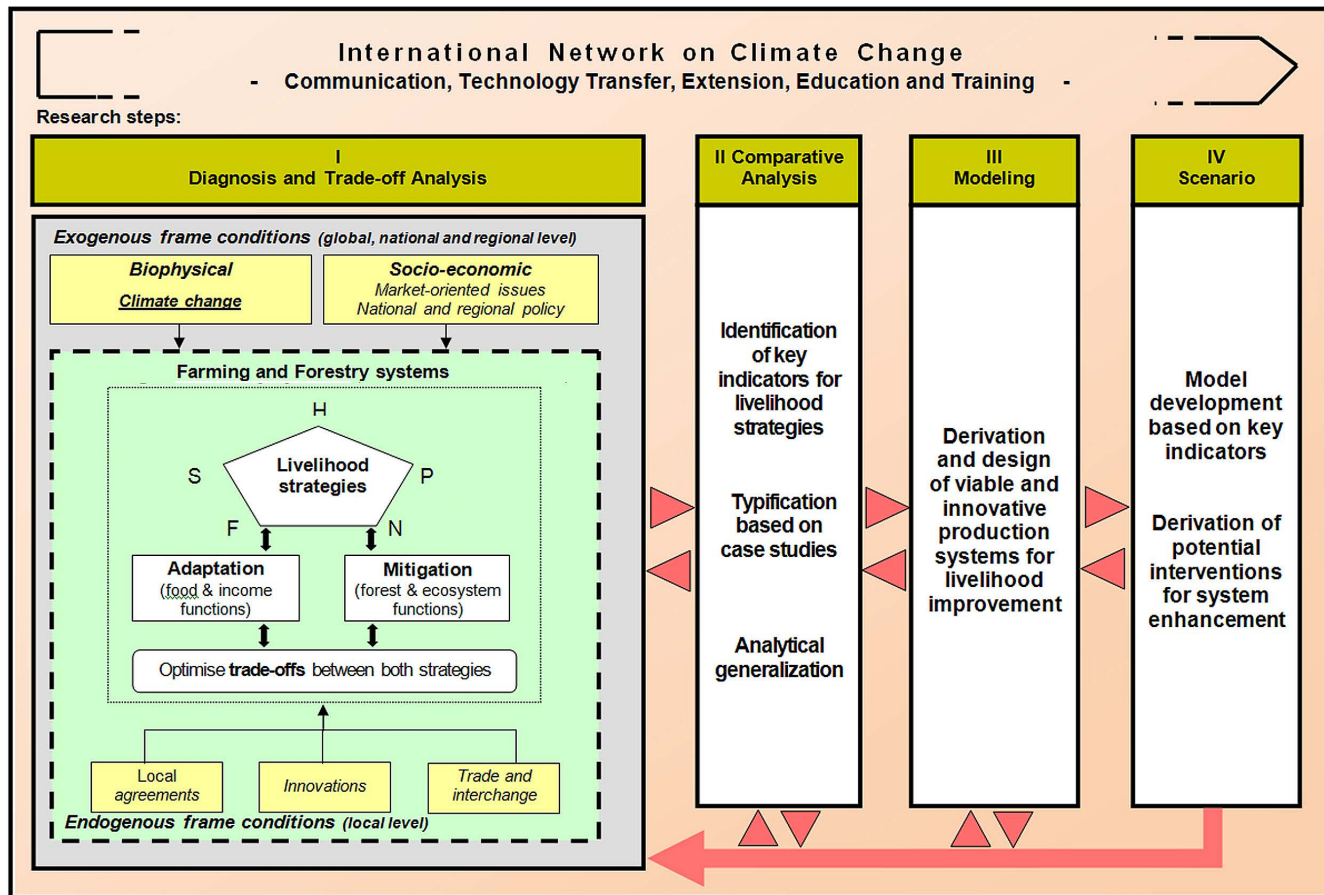
Figure 2. General framework and research steps of the International Network on Climate Change – INCA

17.5°C (IGP, 2005).

As described by Silva et al. (2006) the following climatic trends during the last 50 years were identified: (i) increasing maximum temperatures +0.24°C per decade); (ii) decreasing precipitation (3% per decade); (iii) increasing frequency of freezes.

3. Methodological Framework

There is a distinct need for explorative and evidence-based research on the linkages between sustainability and development as well as on the related trade-offs between efficiency and adaptivity (Rammel et al., 2007). Therefore the network follows a Research and Development approach, integrating case study based research, modeling, and scenario assessment Figure 2. Livelihood strategies are derived and tested for small-scale farms together with local actors, scientists, experts, and students, whereas two main instruments come into application: (i) Socio-economic Field Laboratories; (ii) Agent Based Modeling (a computer based simulation approach). The first instrument provides qualitative and quantitative data on the livelihood strategies farm households use to confront climate related risk in agriculture. The latter uses these data to upscale results from household to community and watershed

levels to assess the economic impacts of predicted land use changes in different farm household groups.

3.1 Socio-economic Field Laboratories
The research is based primarily on two approaches combining the farming and forestry systems and the sustainable livelihoods approach, both focusing on the small-scale farming families (farm households) as units of analysis. These integrate multi-disciplinary and participatory analyses of production and its relationship with biophysical (including climate) and socio-economic determinants (Dixon et al., 2001), taking into account the five livelihood assets (Carney, 1998; Chambers, 1992; DFID, 1999) as key indicators. With an emphasis on vulnerability and poverty reduction, the farm household livelihoods are analyzed in a holistic manner to identify strategically important intervention areas (Krantz, 2001).

The assessment of these systems is conducted using socio-economic field laboratories (FL). "Field laboratories" is an umbrella term for a set of participatory and flexible methods that belong to the action research and uses some elements of the "social learning processes" (Rist et al., 2006). The main purpose is to bring together a large diversity of participants, from small farmers and their representatives in the rural communities, to public authorities, members of development orga-

nizations, researchers and academics. Roughly three out of four of the participants are local stakeholders complemented by academics interacting in a specific working environment close to the reality of informants. The main difference from conventional action research is that all participants become informants, researchers, and teachers (Rist et al., 2006). The aim of the FL is to enable the joint production of knowledge based on a collectively constructed systemic view of farming and forestry systems and livelihood strategies in the different areas of intervention. This research process includes description and diagnosis of the farm household system (and their external determinants) leading to an identification of potential opportunities (intervention design). The latter scenarios take into account the environmental dynamics (including the socio-economic and biophysical conditions) and consequently seek to reduce the farmers vulnerability and overall risk in a flexible manner, complementing their livelihood strategies with feasible options (incorporating the resource constraints into the analysis).

In order to provide the necessary information, several tools have been implemented such as local stakeholder and authority meetings, inception workshops in pre-selected communities, direct observation and the use of secondary data, all this to identify the most suitable communities to work within the study area.

In addition, participatory rural appraisal tools (Geilfus, 2008) were used and conducted in workshops in each selected community. These include trend lines (to understand farmers´ perception of changes over time, with special focus on extreme events) for the general community issues. Natural resource and land use past, present and future maps including extreme events incidences were implemented as part of the natural resource management assessment tools (Figure 3). These were later complemented with transect walks and resource use problem censuses (based on the aforementioned transects). To evaluate the different production systems, seasonal crop calendars, flow chart of activities of the main crops and crop budget calculations based on these charts took place together with historical graphing of production systems (to describe their changes in the past) and preference tree species matrices were used. Finally, for the analysis of problems and solutions, problem (extreme events) priority matrices, and identification of local solutions for agricultural droughts and frosts (major extreme events identified) were carried out.

Moreover, household interviews were completed for 137 households from the selected communities (23% of total households) in order to assess their vulnerability to extreme events with focus on the five livelihood assets. Throughout the research a number of semi-structured interviews with focus on different aspects were carried out, such as agricultural droughts and extreme events impacts in the FHS, land use decision making, local attitude towards agroforestry and forestry systems and their influence on the FHS, and in-depth FHS interviews selected as case studies with focus on land, labor and income allocation. In addition, key informant interviews

Figure 3. Participatory work during rural appraisal in the community of Santiago de Marcatuna in the Achamayo watershed in Junin, Peru. (Photo: François Jost)

were performed with strategic stakeholders of the study area.

Furthermore, natural resource assessment including participant observation on the yield of potato crops and soil moisture measurements in these agricultural and agroforestry systems were carried out to assess the influence of trees in the area. Following the analysis of the different production systems, seeking for land, labor and financial capital allocation efficiency, potential interventions for system enhancement including a trade-off analysis (sacrifice or opportunity cost in terms of benefits foregone; (Grimble and Wellard, 1996) was carried out using the linear programming approach to determine the optimal allocation of production factors. The results were discussed with the farmers.

Finally, as the FL require an intense cooperation among researchers, teachers, and local stakeholders, a number of conferences such as summer schools, meetings, presentations and workshops in different platforms and with all involved organizations took place throughout the research. Accordingly, it is a time-consuming process, which requires the recurrent presence in the field, where each researcher spent a total of 3 months per year in average, being in continual contact with the above mentioned people. Although this ensures the participatory approach from the identification of main local issues and research objectives to the validation of models and future scenarios, FL need trust-building conditions where a good knowledge on the local customary practices might be a prerequisite. This was accomplished by involving 2 doctoral and 2 master researchers from Peru, most of whom were involved since the project elaboration. Most partners were selected beforehand as part of a previously established network, although some key local partners were later identified in a snowball process. Along with its methodological framework the dissemination of the research findings is an ongoing process which takes place inside and outside the study area.

3.2 Agend Based Modeling

In order to achieve a comprehensive understanding of the functioning of the system, an agent-based model was developed applying the simulation software MPMAS (Mathematical Programming-based Multi-Agent System). MPMAS couples a cellular automaton representing a geographical landscape with an agent-based component representing human decision-making (Schreinemachers and Berger, 2011). A mathematical programming matrix describes individual farm households as agents and simulates their decision-making by solving their constrained optimization problems repeatedly over the entire simulation period of 15 years.

In the present application, there are as many agents in the model as there are households in the study site. State variables of the agents include the individual household composition (e.g. age, sex of its members which determines the household consumption requirement and labor supply), available resources such as cash, livestock, trees, land, among others. The core model captures the relevant interactions between the household objectives, productive activities, available resources, and both the surrounding environmental and economic conditions. In each simulation period, each single agent decides about its productive activity by maximizing its expected household utility. Household utility broadly includes the gross revenue consumed by the household and all production costs except household labor.

$$max! \pi_e = R_c(p_e, y_e, a, f) + R_h(p_e, h) + I - \\ V(p_e, a, h, f, M, I) - F(p_e, B, M) - E(e) \quad (1)$$

The household expected utility is maximized as shown in Equation 1 by calculating the sum of expected revenues from crop production (R_c), animal husbandry (R_h) and Off farm income (I), minus variable costs (V), fixed costs (F) and expenditure (E); p_e denotes expected prices, y_e expected yields, a crop and grassland activities, f the part of the crop that is used as animal feed, h animal husbandry activities, M the machinery employed (owned or rented), l hired labor, B infrastructure and e is the energy requirement of the household. This general objective function is standard for all agents. Differences between the agents arise due to different resource endowments and different yield expectations based on agents' experiences over time in the simulation. For this study, the implementation was oriented to reflect the adaptation of farmers' productive systems to climate-induced changes in crop yields and land use area. Hereby farm households (agents) in the model have the ability to adapt to climate change by using the resources available to them by, for example, changing crops due to changing land suitability and maximizing its expected utility considering the changes in the equation variables.

4. Insights in local realities and regional upscaling

Following some of the specific objectives of the research, the present results were obtained from the participatory rural appraisals, participatory observations and the diverse semi-structured interviews applied in the study area.

4.1 Extreme weather events

Farmers notice that there is an increase in extreme weather events and also in the media coverage available on this topic (mainly radio broadcasts). Among community members, communication on the topic and according problems has also increased.

According to the farmers, extreme events are occurring more often in the last 10 years with an overall lack in total precipitation but extreme rainfall events at the same time and overall high and rapid fluctuations in maximum and minimum temperatures. These perceptions are confirmed by measurements carried out by the Geophysical Institute of Peru – IGP (Silva et al., 2006). Such phenomena increasingly affect the farm household systems. After carrying out problem priority matrices regarding extreme weather events in the different communities, farmers considered that their households were mostly affected by frosts, followed by heavy rainfall, droughts (mainly agricultural droughts) and hail events. On the other hand, they acknowledge the potential positive effects of the temperature increase, such as the growth in areas suitable for crops and tree plantations.

The main impact of climate variability and change is an increase of the frequency and severity of extreme weather events and has direct consequences for the food system: crop failure or reduced yields, loss of livestock, destruction of agricultural inputs, increase of land degradation and desertification, increased cost for marketing and distributing food, asset sales, migration and eventual impacts on human development (Morton, 2007), to name a few.

4.2 Agricultural droughts

Agricultural droughts (AD) are defined by the deficiency of water that reduces crop production and is caused by insufficient rainfall or poor water and land management practices. In the study area mainly potato and ulluco crops are affected.

Farmers are aware of the presence of agricultural droughts, but usually they don´t recognize them as a stand-alone weather event, and most of the time they don´t have a name or definition for it. Once explained during the participatory rural workshops, farmers defined and agreed in consensus that ADs occur generally from the 8th day of lack of rainfall during the rainy season, affecting consequently crop growth and their future yield.

If the precipitation continues to diminish due to the above-mentioned climatic trends (Silva et al., 2006) AD are likely to become a severe risk, especially in combination with the reduction of open water sources like springs and lower groundwater availability in the area, both consequences of glacier recession. Generally there is increasing evidence that climate change tend to be more severe, where people rely on weather dependent rain-fed agriculture for their livelihoods (Gentle and Maraseni, 2012).

Moreover, there are low social and human capital resources used to address this issue, mainly due to the lack of organization and technical support and the resulting lack of capacity and knowledge to face the consequences of AD. Especially social capital can play a key role in adaptation processes to climate risks (Adger, 2003). On the other hand, physical and financial limitations could be potentially overcome with an improved organization in the community. The different production systems are not affected homogeneously by AD, as they differ in their exposure, namely by their topography, altitude, soil conditions and vegetation cover. For many farmers the presence of trees in the system usually is considered as strategy to reduce the risks of AD – confirming the promotion of agroforestry systems as mechanism in reduction of the vulnerability of small-scale farmers and legitimate tool to adapt to climate change (Verchot et al., 2007). However, there is no consensus among the famers and some consider the inclusion of trees even as detrimental. The abovementioned lack of knowledge (human capital) related to the benefits of trees in the system to reduce AD therefore limits its presence in the area.

Diversification of crops is considered as suitable adaptation strategy and risk reduction mechanism in smallholder farming (Smit and Skinner, 2002). Because of focusing on few crop varieties and their economic value due to market demands, obvious crop diversification is unusual in the study region. To lower the dependence on single crops and actively strengthen diversification, more human capital expressed in knowledge or labor capacity to balance economic shortcomings would be necessary. Local farmers require higher social and financial assets to compensate losses due to the effects of AD such as increasing their liquidity constraints through better access to loan facilities with low interest rates and the use of more resilient assets like livestock and trees to smooth consumption. In general each one of the 5 capitals (human, physical, natural, financial and social) is at some point a limiting factor that inhibits the response of households to reduce impacts from AD. As emphasized by comparable initiatives, the sustainable livelihood approach is a comprehensive tool for assessing community resilience to climate change (Elasha et al., 2005).

4.3 Importance of trees for livelihood

Mainly the following tree species are used in households and communal lands within the study region. Those are the native Polylepis (Polylepis racemosa Lopez & Pavon and Polylepis incana Kunth), C'olle (Buddleja incana Ruiz & Pav.) and the Alder (Alnus acuminate Kunth and Alnus jorullensis Humboldt, Bonplond & Kunth), as well as the exotic Blue Gum (Eucalyptus globulus Labill) and the Radiata Pine (Pinus radiata D. Don)

After using the preference tree species matrix, farmers all over the Achamayo river basin rank the Blue Gum tree as the best tree species for the study area (Table 1). This is mainly because of their fast growth, wood quality for construction

purposes, firewood properties, high resistance and coppicing capacity. Despite the Alder being classified as second tree species in the matrix because of their physical properties (e.g. for furniture), use as firewood and soil improvement (nitrogen fixation), it is found very rarely in households. This is mainly because of their slow growth and their vulnerability (especially at seedling stage) to be browsed by livestock due to its palatability. Polylepis trees are planted very often because of their coppicing capacity, use for firewood and on occasions for construction purposes. The C'olle is found very rarely and it is used just as firewood and as a windbreak or fence for protecting the crops from livestock. The Radiata Pine, although rarely occurring in the landscape, is being planted more often and preferred by some of the households because of positive experiences with this species in other communities in the Andes (Vergara and Barton, 2013). This is mainly because of their symbiotic properties with commercial mushrooms (e.g. Boletus spp.), their good physical properties for construction, and the market wood price.

Table 1. Community tree ranking: genera in the columns were contrasted with genera in rows. Farmers were asked to choose their favored tree among the pairs.

	Eucalyptus	Alnus	Polylepis
Eucalyptus			
Alnus	Eucalyptus		
Polylepis	Eucalyptus	Alnus	
Buddleja	Eucalyptus	Alnus	Polylepis

Generally farmers in the study region recognize the presence of trees as beneficial, also as measure against negative impacts of climate change (Verchot et al., 2007). They appreciate the reduction of the impacts of frost events on crops, the provided wood supply and improved soil conditions, whereas they are aware of different characteristic of different tree species: e.g. nutrient enrichment by Alnus and nutrient reduction by Eucalyptus. Trees also provide an additional direct income source and are occasionally managed to provide future financial assets. Such safety net strategies of smallholders, especially using Eucalyptus, are also known from other regions (Kebebew, 2010). Although during the participatory rural workshops farmers felt the need of increasing the presence of trees in the area, many of them have limitations due to the lack of land and other particular needs which resolve into the reluctance to plant trees (e.g. lack of technical knowledge or support, lack of seedlings and opportunity costs). Finally to be taken into concern is the fact that farming households depend on short term benefits and long term equivalents from trees are outside of their management portfolio.

Recently the potential of income generation for small farmers from carbon market mechanisms has come into the discussion and scenarios of up to 15% increase in per capita income, reducing in 9% the number of Andean farmers below the poverty line, have been presented (Antle et al., 2007). Still,

these numbers rely on prices above $50 per MgC and with the ongoing decline in carbon prices such models have to be critically revised. Nonetheless, the previous did neither take into consideration the effects of agroforestry systems in crop productivity, nor the additional income generated by the sale of trees, and therefore income from these activities could be further increased.

4.4 Key aspects in model development

The purpose of applying the agent-based modelling approach is to understand how expected climate change in the Andean Region will affect the farm households' socio-economic status as well as the land use of the study area. Based on the hypothesis that small farmers of the Andean region are aware of the ongoing climate change and are trying to adapt their traditional productive practices to cope with these changes, the model is used to understand the effect of the various constraints the farmers face due to resource availability.

A scenario-based analysis explores the impact of changes in climate conditions. Resource decisions and decision outcomes of each model agent depend on the surrounding environment (exogenous to the household), including changes in land use, market prices and policies, as well as on decisions endogenous to the household like selection of crop mix and productive technology choice. The different production and investment alternatives used to parameterize the model are the result of a collaborative household and market surveys in the project region in 2011 and 2012. This data is to be complemented and adjusted with information from literature reviews, expert opinions and participatory rural workshops. Priority is given to primary empirical data coming from the households of the study site to assure the incorporation of real-world decision alternatives and rules of decision-making and interactions. In that sense the involvement of the stakeholder in the model development and validation is particularly beneficial for the quality of the ABM.

Modeling results are important on both hierarchical levels of the system: the household level and the community level. Households are expected to react differently to climate change depending on the pool of resources they command and the constraints they have to confront (Mendelsohn and Dinar, 2009). By analyzing and comparing choices made by farmers who face changing climate conditions, ABM can uncover how farmers adapt to current climate. Using this approach, it is possible to examine numerous farm decisions including farm type, irrigation, livestock choice, crop choice and a combination of them (Mendelsohn and Dinar, 2009). In each case, the sensitivity of these endogenous choices by farmers to climate reveals their climate adaptation. This level of analysis is very useful for the development of targeted specific interventions instead of "one size fits all" type of policies, which becomes increasingly important with the certainty of site specific stressors and adaptation demands (Füssel, 2010; McDowell and Hess, 2012).

ABMs are simulation tools to examine the plausibility of our hypotheses about the functioning of eco-ecological systems. The description of individual agents as well as their interactions with their environment provides furthermore an assessment of the importance of households' variability and decision making in the context of the specific locations and history. The incorporation of ABMs in socio-ecological research bears thus a considerable potential to improve our scientific understanding about complex adaptive systems as our case study is. There are, nevertheless, methodological challenges for the development of such models related to a main obstacle: the models need to capture the basic principles of the systems in order to be reliable under changing environmental conditions, without compromising their applicability in specific cases. Certain predictions of the consequences of various scenarios are only possible if an ABM is structurally realistic. This requires comprehensive analyses of model results against different situations observed in the field.

5. Conclusion and outlook

The presented project is work in progress. The results are preliminary and the agent based modeling approach is still in developing and needs validation after being finalized. Nevertheless the potential to couple socio-economical with biophysical models and to study the emergence of collective responses to environmental changes is already recognizable (Balbi and Giupponi, 2009; Schreinemachers and Berger, 2011). The combination of participatory methods, expert knowledge and reliable methods for ex ante evaluation of adaptation strategies at household are urgently needed to provide crucial information on the impacts in the context of climate change – especially in regions where complex, (semi-)subsistence agricultural systems dominate (Claessens et al., 2012). Such information is the baseline for successful evaluation of adaptation measures and reasonable interventions. So far small-scale community efforts are still rarely acknowledged to have impact also beyond the local level (Ireland and McKinnon, 2013), a challenge which is tackled by this project. It also meets the need to model co-evolutionary dynamics in natural resource management systems to enhance stakeholder participation. The assessment of multi-level interrelations in such network (Figure 4) supports the apprehension of the complexity in small-scale farming and forestry systems and promotes shared contextual understanding among stakeholders for dialogue-oriented methods (Rammel et al., 2007). Hence, the present initiative follows the concept of Vermeulen et al. (2012) in addressing not only scientific capacity but also the capacity of users to demand, interpret and apply scientific outputs effectively to eventually tackle climate change impacts. The expected final outcomes as well as the integrated network approach itself are in accordance with recently published research demands by IPCC (2014):

- research on adaptive capacity involving the traditional knowledge of ancestral cultures and how this knowledge is transmitted
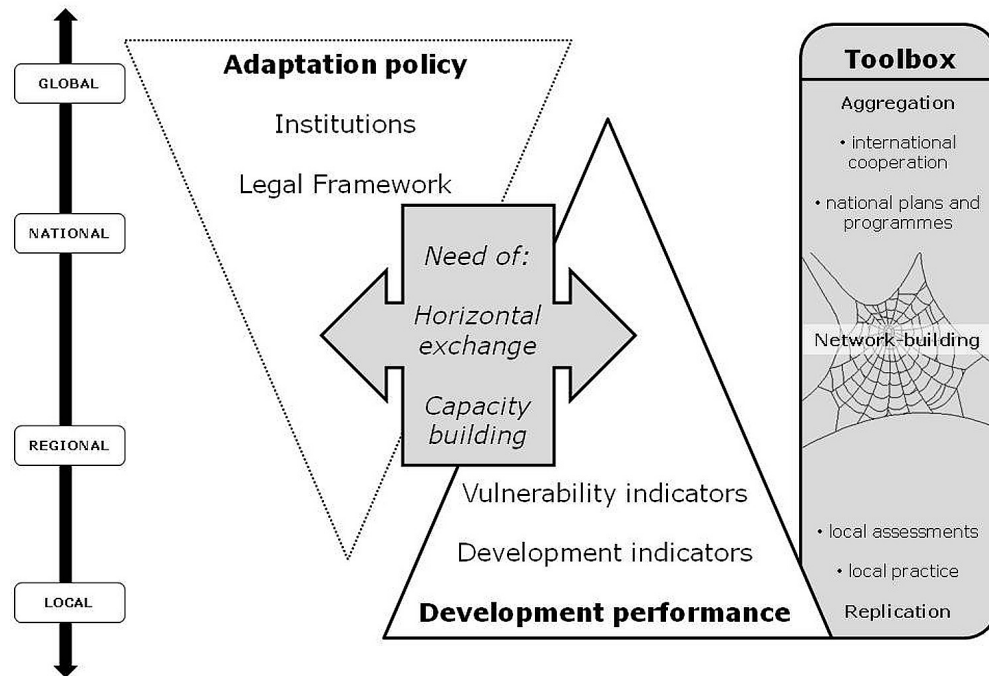
Figure 4. The scheme (modified after Brooks, 2011)) illustrates both levels, "top down"-adaptation policy and "buttom up"-development performance. The filled box (right) exemplifies instruments to enable the central exchange and capacity building.

- research on adaptation and the scientific understanding, linking indigenous knowledge with scientific knowledge
- need for updated and available data sets that feed basic and applied studies
- interdisciplinary integrated studies to understand complex interactions [. . .] need to address vulnerability and foster adaptation; encompassing an inclusion of the regions' researchers and focusing also on governance structures and action oriented research that addresses resource distribution inequities

The overall aim is to contribute to the international debate within the United Nations Framework, Convention on Climate Change (UNFCCC) from the bottom up to consider the needs and experiences of local stakeholders in using natural resources under a changing climate.

Acknowledgments

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