

Vulnerability and adaptation to climate change of rural people living in the central coastal plain of El Salvador

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The main objective of this paper is to explore more appropriate conceptual frameworks and methodologies to assess current and future climate vulnerability. The prior to facilitate the inclusion of adaptation into local endogenous development processes, including actions that influence the decision-making process at the national and municipal level.

To assess climate vulnerability of the selected territory¹ (further referred to as territory) a systemic approach was adopted, incorporating the central concept of adaptive complex system, and applying it through an inter-disciplinary approach. The territory is considered a human system², and as such, it has a dynamic and non-linear behavior and it is able to develop emerging functions (e.g.: resilience and adaptive capacity), allowing the system to resist and adapt to change. The territory was identified and characterized through the natural, economic and socio-cultural local environments of human populations that live there. Therefore, its boundaries were set based on criteria related to socio-economic organization and prevailing natural dynamics as well. The territory was also considered a social landscape since it includes human systems in which social actors play a fundamental role, considering inter-linkages between natural and human systems.

Vulnerability of a natural or human system to climate exposure is defined as a dependant variable of three first order-explanative variables, namely: climate exposure, resilience and adaptive capacity. Climate exposure is considered as a local threat. Resilience is the attribute allowing the system to absorb, within a coping range, natural or social shocks and to further recover from disturbances or impacts, conserving the same stability domain³. Adaptive capacity refers to the potential of the system to progress and adapt to changes without collapsing, through learning processes that increase its coping range and capacity to self-organization.

Second order-variables are associated to the first order-explanative variables of vulnerability. Climate exposure is addressed through an index, integrating dry and wet climatic extreme events and temperature extremes. Resilience is captured through flexibility (degree), mechanisms of control (type and effectiveness) and structural coupling (type and degree). Adaptive capacity is addressed through three variables, namely: potential of resources (type, availability and accessibility), experimentation and innovation (type and degree) and complexity of organization (type and degree).

The integrated assessment incorporates natural and social⁴ explanative factors that produce or increase current and future climate vulnerability. The previous facilitates identification

and prioritization of adaptation measures and strategies that prevent or minimize impacts related to climate variability and change. The increase of local resilience and adaptive capacity constitutes the basis for the local adaptation strategy.

The methodology to assess climate vulnerability and to develop the adaptation strategy includes the following steps: a) identification of the human system to be assessed and whose adaptation strategy is to be developed, b) integrated assessment of current climate vulnerability, considering baseline socioeconomic and climate scenarios, c) integrated assessment of future climate vulnerability including local projected socioeconomic dynamics and climate change, and d) development of an adaptation strategy to address the projected local climate change and to be considered and incorporated within the existing local development plans, and eventually at the national or municipal levels.

Participation of local people and organizations in each of these steps was very active, playing an increasingly leading role. Participation included consulting and validation processes, field surveying, information collection and dissemination, education and awareness raising, information and criteria exchange, analysis and prospecting processes. Local knowledge, along with theoretical knowledge, was fully considered in order to: understand local history related to natural and social processes and land changes; analyze and project economic, socio-cultural and natural events and dynamics; and develop strategic planning to face climate change through a local adaptation strategy.

The historical socio-natural dynamics of the territory was preliminary understood to set the appropriate socio-cultural, economic and natural criteria to define the territory boundaries. As well, existing coupling and linkages between natural and social dynamics were taken into account. In that regard, geographical areas, where human communities are settled, were selected, taking into account their social network and organization, the dynamics of local economy and the consolidated local initiatives focused on the promotion of endogenous development⁵. As well, the geographical space of the natural landscape system, referred to as central coastal plain⁶, was partially considered, and so were those of the four natural landscape sub-systems influencing the natural dynamics of the territory, namely: the two coastal plains La Libertad-San Vicente and Usulután, and the two volcanic massifs San Vicente and San Miguel-Usulután. Finally, the seven watersheds whose dynamics affect or are somehow linked to the identified human communities, were included, namely: El Pajarito, El

Guayabo, Cuenca baja del río Lempa, El Espino-Borbollón, El Potrero, Nanachepa y Aguacayo.

The territory has an area of 1,152.5 km² including large extensions of low lands which are up to 2-60 masl along the Pacific coastal fringe. Northward, moderate to high slopes are abundant, presenting elevations from 100 to 1500 masl, near to the volcanic massifs; and 2,100 to 2,300 masl, in the volcanic cones. Some 6,725 rural families are currently living within the territory, which is about 26,900 people, with an average of 4 members per family. A 30-map atlas was developed to support current and future local planning and decision-making process⁷, including a zoning of flooding risks areas, in order to illustrate local socio-natural dynamics.

In order to define by 2004 the socioeconomic and environmental baseline and to project it by 2015, a system of variables and indicators, linked to the respective dimensions of the socio-cultural, natural and economic environments of the territory, was established. The referred system was in turn linked to the appropriate second-order variables of vulnerability, which are associated either to the first-order variable resilience or to adaptive capacity. A composite vulnerability index (VI) was calculated to estimate the magnitude of current and future climate vulnerability. Climate exposure was integrated to the VI through the calculation of a climatic threat sub-index (CTI), which incorporates different levels of local threat related to temperature and precipitation extremes (extreme wet and dry events).

The socioeconomic and environmental baseline scenario expresses the territory current state, in terms of strengths and weaknesses contributing to determine the values associated to two of the three explicative variables (resilience and adaptive capacity) of climate vulnerability by 2004. The future socio-economic and environmental scenario expresses the territory projected state by 2015 under climate change conditions, whose values could contribute to maintain, increase or decrease the current vulnerability level. As well, baseline and future climate scenarios were developed by 2004 and 2015 respectively to calculate current and projected values of the 5 climatic indicators integrating the CTI.

Current and projected conditions of the socio-cultural, natural and economic local environments by 2004 and 2015 were determined through the calculation of the values for the 69 indicators, and for the associated first and second-order variables of vulnerability. The calculation of the current and future VI of the territory allows to integrate, in a unique mathematical expression, current and future values of the three territory sub-indices, namely: resilience (R), adaptive capacity (A) and climatic threat (CTI), also referred to as climate exposure (E), as follows: $VI = [2E - (R + A) + 2]/4$, with $IV_{max} = 1$, $IV_{min} = 0$.

The values of the sub-indices resilience and adaptive capacity were calculated through the consolidation of the values of those variables for each local environment. For this, baseline and future values were calculated for each indicator and dimension. Among the whole 69-indicator system that characterized current and future territory conditions, 23 refer to the normative, cultural and psycho-social dimensions of the socio-cultural environment; 31 indicators are associated

to the natural and socio-natural dimensions of the natural environment; and 15 indicators are linked to the productive, distribution-consumption, and commercial dimensions of the economic environment.

Future socio-economic and environmental scenarios were developed considering the linkages between climatic, socio-economic and environmental local effects (bottom-up approach) within the general context of national macro-policies (top-down approach). Future scenarios were developed following a four-step process: a) Analysis of current national macro-policies and key indicators (further referred to as driving forces), b) Integrated analysis of the dynamics generated by the national macro-policies and the driving forces projected by 2015, c) Definition of the local expression of the macro-policies and the driving forces, for each dimension and environment by 2015, d) Definition and local validation of the local socio-economic scenario by 2015, based on the future values of the whole system of indicators.

In order to develop the local adaptation strategy to face climate change, its nature and scope were defined, including the geographical, temporal and thematic scope. As well, the principles, beneficiaries and the outline of the monitoring and evaluation system were defined. Three specific objectives, linked to the socio-cultural, natural and economic local environments respectively, were identified, to which 8 lines of action and 28 adaptation measures were associated and prioritized, based on categorized values of the whole set of indicators by 2015. The strategy was developed by the research team⁸ together with local actors and counterparts who actively participated in identifying, prioritizing, structuring and validating the set of adaptation measures. This process was built on the results of the integrated assessment of current and future vulnerability. Adaptation measures were selected through the identification and prioritization of the main problems associated to the various dimensions for each local environment. Adaptation lines of action and measures were defined with the view to overcome the identified main problems which were expressed through the projected values of the 69 indicators by 2015. The purpose of the strategy integrates the three specific objectives for the territory. The scope for each adaptation measure was developed, including specific actions, geographic location and responsibilities for implementation. Some measures could be adopted and executed by rural families and their local organizations, and others at the municipal or national public level, according to the relevant legal mandates.

Baseline climate is referred to 1961-1990 climatology which is mainly influenced by the Pacific Ocean waters and the meteorological systems associated to the inter-tropical convergence zone (ITCZ), among other atmospheric processes. The territory is one of the most vulnerable areas of the country to climate extreme events, due to the yearly occurrence of droughts and floods. Floods dynamics present a pattern linked to different factors, such as ITCZ-activity, hurricanes and La Niña event. Local annual mean precipitation is up to 1500 mm close to the coastal fringe, increasing up to 1700 mm northern. During the rainy season, in July and August there are several periods from 5 to 15 consecutive days without rain, which affects local water availability. Maximum mean annual

temperatures are from 31°C, close to the coastal fringe, up to 35-36°C northern along the Lempa River banks. Estimated values of linear trends indicate a warming process of approximately 0.04°C per year, which means that the mean annual temperature increased approximately 1.2°C during 1961-1990.

Future climate scenarios projected maximum and minimum temperatures and precipitation by 2015, using statistical downscaling techniques, the 1961-1990 and 2006-2035 climate records and the A2 scenario⁹. Climate scenarios generated parameters and criteria used as framework and basis to project by 2020 the 5 indicators of the future CTI, which captures local precipitation and temperature extremes, either for baseline and future climate scenarios. To measure climate impacts by 2015 on productive activities and some environmental processes, mainly hydrologic and hydraulic, future levels of climatic threats were quantified applying some appropriate criteria.

Due to CTI future values, the territory would have moderate to high adverse effects on local economy, quality of rural people life, economic infrastructure and natural systems (terrestrial, aquatic and coastal-marine). Current climate impacts would worsen due to the combined effect of the temperature increase and more frequent recurrence of consecutive drought days during the rainy season. Water availability would decrease and therefore there would not be enough water for rural families, crops and livestock, due to the recurrence of extreme dry years which cause increases of evapotranspiration. The frequent recurrence of extreme wet years and floods would increase the damages and losses of utilities and equipment, increase sedimentation and damages of existing sewage systems and dams, and damage roads, drains, bridges and docks. More frequent fires and plagues would affect forests due to segmentation, and floods would undermine the basement of mangroves which in turn would deteriorate and reduce. Native and migratory species, mainly birds, would present anomalies in their behavior and development, due to the loss of their habitat. The combined effect of floods and tides would increase sedimentation and erosion of low coastal lands, soils and aquifers. It is worth noting that the CTI only incorporates indicators related to precipitation and temperature extremes, which would not capture the wide range of the climate change-related threats on human and natural systems within the territory, as an eventual sea level rise.

Current and future VI were calculated for each of the 6 geographical areas¹⁰ settled by local organizations within the territory. The future VI would increase in the whole territory by 2015. Either resilience or adaptive capacity would increase their future values, due to existing local processes of autonomous adaptation. However, the value of climate exposure (CTI) would increase high enough so that the magnitude of the increase of resilience (R) and adaptive capacity

(A) would not offset the weight of future CTI or climate exposure (E) within the mathematical expression of the VI. Taking into account that the future value of the CTI would be the same for the whole territory, the different VI future values within the territory would be determined by future resilience and adaptive capacity for each environment and for each of the 6 particular geographical areas.

With regard to future adaptive capacity, only the socio-cultural environment would increase its value in the whole territory, therefore, it would contribute the most to improve such variable by 2015, due to local plans directed to consolidate and improve the functioning of the social network and organization. The economic environment would significantly decrease its contribution to future adaptive capacity due to the lack of relevant public technical assistance, credit, technology transfer and research, and to the decline of family incomes. Even though, roads would be improved due to cooperative efforts with the municipalities. The natural environment would hardly contribute to future adaptive capacity, due to the projected increase of environmental deterioration and to the lack of land planning. Such processes would affect the performance of essential environmental functions and of those that support life and human activities¹¹.

Future resilience of the natural environment would present the lowest values by 2015, contributing the less to the future value of this variable, due to the uncontrolled deterioration of local natural systems. The future economic environment would significantly contribute to resilience due to the strengthening of productive organization in some geographical areas, which includes economic and agricultural diversification, productive efficiency improvement and the adoption of species with a wider coping range to better face climate variations and changes. Resilience of the socio-cultural environment would increase its future value in the whole territory by 2015 and would continue contributing the most to the value of that variable due to local initiatives, promoted by local organizations, which include the strengthening of local capacities and development opportunities, the improvement of local warning systems to face floods; the rescue, dissemination and enrichment of traditional local knowledge; the appreciation and consolidation of cultural and historical identity; and the broadening of alliances at the national, regional and international level, with other relevant actors dedicated to promote local endogenous development in a sustainable manner.

Even though the levels of climate vulnerability in the whole territory would increase by 2015, they would still remain in an intermediate category, similar to the baseline conditions. The previous due to the fact that projected socio-economic and environmental scenarios are including local autonomous adaptation. This could explain the relatively high values projected for the resilience and adaptive capacity sub-indices. Would such local efforts not be assumed nor implemented by local actors within their local development initiatives, as they are now projecting; the contribution of the three environments to the two referred indices would decrease significantly, and thus the future VI would be in turn increasing. Projected values of indicators and associated variables facilitated, for each environment and for the whole territory, the identification of the main weaknesses and strengths whose overcoming or strengthening could contribute to decrease vulnerability associated to future climate change. Adaptation measures included in the proposed local adaptation strategy would constitute an additional effort to ongoing and projected autonomous adaptation efforts incorporated by local actors in their development planning.

The three fundamental principles of the United Nations Framework Convention on Climate Change (UNFCCC) were the basis for developing the local adaptation strategy, which was designed with the view to increase resilience and adaptive capacity of socio-cultural, natural and economic environments. The previous to prevent, reduce or minimize projected impacts of climate change (precautionary principle). As well, adaptation measures were thought to strengthen efforts to improve the quality of life of rural local people (equity principle), and to support local efforts directed to take steps to obtain technical and financial support within the UNFCCC multilateral process (polluter pay principle).

Local rural families would be the beneficiaries of the adaptation strategy and social local organizations would be directly responsible for promoting the strategy and to follow up its appropriate implementation. The strategy articulates socio-cultural, natural and economic local environments, setting adaptation measures with the view to strengthen resilience and adaptive capacity of such environments through integrated strategic plans and initiatives.

The purpose of the strategy is to strengthen organization and capacities of local rural people to incorporate in their socio-economic activities adaptation to climate change, within a land planning framework for the territory located in the central coastal plain of El Salvador. The specific objectives of the strategy are: i) to increase the climate change coping range of rural local livelihoods through economic diversification and the adoption of appropriate productive systems, technologies and practices; ii) to strengthen local capacities to incorporate climate change into land management through the improvement of local knowledge on land planning and the setting of criteria and management plans; and iii) to enhance local organization and capacities to influence public policies and priorities at the municipal and national level, through the strengthening, dissemination and appropriate implementation of the relevant legal framework.

The monitoring and evaluation (M&E) system to be set for the adaptation strategy should be based on the future follow up of the 69-indicator system, which was established to assess current and future climate vulnerability and adaptation. This would allow local people to evaluate the influence or effect of the adopted adaptation measures on vulnerability, through the various dimensions that characterize the socio-cultural, natural and economic environments within the territory. The M&E system should consider indicators related to impacts, effects, outcomes and progress in order to measure: a) the contribution to decrease vulnerability to climate variability and change; b) the effectiveness of implementing the strategy, in terms of the timely availability of the various required goods and services; and c) the level of expenditure according to the assigned budget.

The definition and adoption, from the beginning, of a conceptual framework consistent with the nature of human systems to be assessed, generated the appropriate criteria to set the boundaries, characterize the territory and address climate vulnerability and adaptation. The adoption of a conceptual framework, integrating natural and social processes and identifying the explicative factors of climate vulnerability, supported

the development of the local adaptation strategy, including the prioritization of the adaptation measures. The development of a methodological approach appropriate to national circumstances, with the required transparency and effective local participation, facilitated to local actors the adoption of the process and outcomes, playing progressively a leading role. The inter-disciplinary approach adopted by the research team contributed to enhance national capacities to develop integrated assessments and strategies, incorporating the interactions and couplings between social and natural systems.

There is a local knowledge, which has been either transmitted by oral tradition or empirically acquired, concerning the history and current trends of natural and social processes, which was rescued and incorporated into the analysis and prospecting processes to enrich and complete technical knowledge and proposals. The scope of the local adaptation strategy extends beyond the territory through activities directed to influence the public policy-making process, in order to incorporate adaptation to climate change within the development agenda at the national or municipal level.

1 A geographical space, managed under the prevailing economic, social and political dynamics.

2 Human systems are tightly related to human beings and society, having specialized information processes and structures.

3 The system conserves the same structure, functions and mechanisms of control.

4 Social refers to economic and socio-cultural human activities, including political, technological and scientific issues.

5 Local endogenous development is a type of process promoting local people to enhance their knowledge and take control of natural and social factors

that either determine or impact their territory, and offer opportunities for human development.

6 It is part of the geological landscapes and morpho-structural units of El Salvador. There is no zoning of natural landscapes as per the geocology.

7 A comprehensive database was developed, including the 30-maps-related shape files. The database was submitted to local counterparts who were trained in the use of the software application ArcGis.

8 It was established under the Regional Adaptation Project named Strengthening capacities for Stage II Adaptation to Climate Change in Central America, México and Cuba, which in the case of El Salvador, was implemented by the Ministry of Environment and Natural Resources (MARN). The referred project was funded by the GEF through the UNDP, from July 2003 to April 2007.

9 A2 is a family of emissions scenarios, according to the IPCC Special Report on Emissions Scenarios, 2000.

10 The two main social organizations (counterparts to the present study) have established 3 micro-regions and 3 zones in the West and East banks of the

Lempa River respectively.

11 Referred to as goods and services as per the environmental economics.