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# SilVIo, Modelling Social Vulnerability under a Local Perspective

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**Abstract:** The objective of this research is to develop and to model an indicator of social vulnerability as part of a multidimensional, multivariable and non linear process. Social vulnerability can be considered as a complex system, in which many relationships in society and environment can be described by considering individual and structural factors. Numerous studies provide tools to analyze and revise social systems but these tools were developed generalizing and overviewing the relationship among many intermediate realities, for another type of systems, more formalized and conceptualized. Social systems do not have this classical formalization. The development of the **S**oc**I**a**L** **V**ulnerability **I**ndex, SILVIO, is an interesting new approach to the research on environmental systems. SILVIO integrates particularly the social (SVI) and ecological (CCL) aspects of a spatially defined region, using as data basis not only statistical information, but as well the perspective and experience of its citizens in their local reality. In this paper, we used the concept of social vulnerability to develop the social part of an index, SVI, a local reality considering the man-environment relationship in a more structured approach. SILVIO displays in a comprehensive way the local situation generated by actors in the system. Furthermore, SilVIo represents the work with local communities and development of actions that include the citizens' perspective, a very important item in the quest to find fields for action which give answers regarding the basic needs in the area of research. Finally, our scientific target is to develop a social vulnerability index for the local reality which uses complex systems tools, dynamics systems and data mining to represent the citizens' local perception.

***Keywords**:* Local Social Change, Social Vulnerability, Eco-social Index, Data Mining, Dynamic Systems.

## 1 INTRODUCTION AND DESCRIPTION OF THE PROBLEM

Ancash is an administrative Department located in the northwest of Peru and its capital, Huaraz, in the mountain region of the department, called Peruvian Cordillera Blanca. This area exhibits an abundant cultural and natural heritage, expressed by the rich culture of its rural settlements and its protected natural spaces. The geographic region of research is situated in an area delimited by the Quebrada Shallap canyon – stretching from Nevado San Juan, a mountain with an altitude of almost 6.000 m, to the southwestern city of Huaraz (at about 3.000 m altitude) - comprising the localities of Llupa, Unchus, Junco, Paquish-ca, Coyllur, Ichoca y Los Pinos.

This region is being closely monitored by the national government because it represents an area rich in important natural resources such as superficial water bodies and mining deposits (the mining sector represents with 9,6% the third most important monetary contribution to the GDP). In spite of the economic contribution of this geographical region to the GDP, there is 27.4% poverty rate in the Ancash Department with a total population of 1.063.459 (INEI 2014).

The concept of poverty utilized in this context follows Chang who associates groups living in poverty with spontaneous human settlements, precarious housings in areas at risk and disordered territorial occupation (Chang 2005.). There seems to be some reason for optimism as the poverty rate for Ancash has reduced between 2004 and 2009 from 32% to 22% (UNSAM 2010). Unfortunately, statistical data also shows an increase in infant mortality (21/1000) and migration in Ancash (INEI 2014), therefore it is possible that both phenomena belong to poverty classes.

Huaraz is a zone very sensitive for social conflicts and a region that is highly vulnerable, in the social as well as in the geographical sense, although in the light of disasters of any kind *"…we are all* exposed to manifestations of vulnerability, in different degrees, but in the end exposed" (Chang 2005). The particular vulnerability situation of Huaraz and the "climate-glaciers-water-society dynamics" are described in an extraordinary manner by Carey: "*Disaster exposes wealthy survivors to the same vulnerability and precarious living conditions as the poor. A major post-disaster threat to middle-and upper-class victims is the unrestricted movement and social mobility of the lower classes into spaces previously reserved for them. In Huaraz, spatial mobility and the lack of physical barriers to demarcate space created a social disaster for urban survivors."* Furthermore the author mentions that "Local residents living close to glaciers or directly in glacially fed watersheds endure the highest cost of glacier retreat because they often pay with their lives, their families, and their communities.", (Carey 2010).

Facing the situation described above, we present the idea to develop an indicator of social vulnerability, based on variables that are valued as important by regional experts. Experts describe a person who participates in the Interview but not necessarily an academicals one or with technical know-how for Huaraz. These are aspects defined as "very important" by the local interviewers as well as hierarchically weighted topics considered as priority for their major contribution to the family-household income. The data collection for this research was done through direct surveys and put in the SVI, the social component of SilVIo. In this way is SilVIo a system of indicators. In the dynamics of decision-making it is necessary to transmit the information, situation or conflict to the decision-makers in a representative and precise way, trying to minimize the considerable influence of uncertainty in the data.

Indicators can offer decision-makers more representative information from the data and they play a very important role for a fluid communication between the stakeholders, i.e. local population and decision-makers. Related to this idea, Bauer (cited by Mondragon 2002) defines: *"Social indicators (...) are statistics, statistical series or any other form of indication which help us to find out where we are and where we are headed regarding determined targets and objectives, as well as to evaluate specific programs and verify their impact."* A well structured indicator allows decision-makers to manage and have at their disposal a lot of information about the dynamic of the occurrences, "indicating" the nature of the system.

In the current reality, where the time of discussion and execution in decision-making processes is reduced and where it is not always easy to obtain complete and/or reliable data about the system of research, it becomes necessary to generalize and disseminate the information in order to create more efficient mechanisms for the data acquisition. The main intention is to construct indicators for an area which may be used also in other areas, ensuring the "universality" of the generated indicators (Rincon 2009). The socio-environmental, economic and political reality can differ very significantly from one country to another but the challenges are global and common, for example social vulnerability.

## 2 ANALITICAL FRAMEWORK

An analysis of social vulnerability can be conducted by developing and studying indicators. Traditionally, a social vulnerability indicator describes poverty, demography, social resilience, environmental damage, presence of ethnic groups, inequality coefficients and sustainability indices, but all of them separately (OEA 1993; Chang 2005). In most cases, when we analyze the interviews conducted, in the field research, we find that decision-makers in Huaraz discussed a socio-

environmental indicator by building separate social and environmental indicators. Thus it is left to the decision-maker to correlate both indicators in the decision making process.

For the parameterization of SilVIo, several visits to the research area and interviews were conducted with regional experts, including residents, heads of water user associations, representatives from environment and water authorities, local authorities, neighborhood leaders, tourist guides and researchers in this geographical area.

SilVIo is presented as a system of indicators. A social one, denominate Social Vulnerability indicator, SVI, and an environmental one, representing de local climate change, LCC. In this work only its social component SVI is introduced, representing the most distinctive elements of social vulnerability. These particular thematics are weighted and prioritized by order of significance by the before mentioned experts through a questionnaire. The results were analyzed with a fuzzy methodology from Gil-Aluja y Kauffmann, (Gil-Aluja 1990), and they show a similar structure as a vector and is presented in equation (1). The SVI vector presents mining, tourism and agricultural production as activities with major economical contribution to the household income. The database for the model was collected through a systematic revision of literature and empirical field research (interviews). Guided interview techniques (Reuber 2013) were applied and also fuzzy expertons method (Gil-Aluja 1990), in systems dynamics.

The structure of the SVI was elaborated in different stages: a selection stage for the variables with interviews and consultation to experts and another stage of ranking the variables trough quantitative weighting, i.e. assigning to each criterion a value on a numerical scale between 0 and 10. This paper introduces the identification and stochastic quantification of a social state/condition/situation for a determined space and time called temporal social vulnerability indicator, SVI(t). To ensure the continuity of settlements in the proximity of the Quebrada Shallap canyon, the presence of a group of conditions that allow this continuity is necessary. The loss of one or more of these conditions can induce the partial or total loss of human groups (cultural societies) in this geographical area. This loss is not deterministic (cannot be anticipated) but a situational analysis allows to deduce the possibility of occurrence of the event and this is called vulnerability (risk of occurrence of the least desired event).

The analysis of this part is descriptive and the basis for the predictive structure of the indicator. The probabilistic calculation of occurrence in a time t (space of time after the actual state) is called primary social vulnerability indicator (SVI) and it is a measure of the probabilistic magnitude of the risk described above.

The indicator can be expressed as:
I(V1, V2, ….VK), where V1 $\varepsilon$ RN1, V2 $\varepsilon$ RN2,…Vk $\varepsilon$ RNk .

The indicator is the function: f(RN1 x RN2 x ,… RNk), generating:

$$\begin{pmatrix} V1 \\ V2 \\ . \\ . \\ Vk \end{pmatrix} \quad \begin{matrix} \varepsilon\ RN1 \\ \varepsilon\ RN2 \\ . \\ . \\ \varepsilon\ RNk \end{matrix} \qquad (1)$$

I: RN1 x RN2 …. RNk

The set space is Rm and the subsets are in the space RN (through expert information). Qualitative state and dynamic in the region are described with the variables mining, agriculture, tourism, migration, illiteracy, health, poverty, infant mortality and housing (with utility services: electricity, water, WC). From all of these mining, agriculture and tourism were selected due to their major economical contribution to the household incomes.

## 3 DATA

The following available data was analyzed: a) Population censuses and the statistical annals,(INEI) and b) Data collections with respect to the whole country, the Ancash department and the Huaraz province(MINAM).

Comparison was made using data up until 2005 as there is information available for all administrative levels for this period. Mining is found to be a variable for analysis because it is an economic activity with a considerable contribution to the national GDP,Table 2, being also the leading contributor at departmental level and one of the activities valued as “very important” in the hierarchy by the interviewed experts. It should be emphasized once more that this hierarchy expresses the influence of mining in the household income. The two commodities (copper and gold) have been selected and compared regarding their production volume for Peru and at the departmental level. Table 1 displays the values for the years 1991- 2005.

**Table 1.** Volume of (Copper-Gold) production in Peru and in the department Ancash. (Tons of fine content). Source MINAM

| | Peru | | | | Ancash | | | | Copper Dept. Share | Gold Dept. Share |
|---|---|---|---|---|---|---|---|---|---|---|
| Years | Copper Prod. | Growth Rate | Gold Prod. | Growth Rate | Copper Prod. | Growth Rate | Gold Prod. | Growth Rate | | |
| 1991 | 382277 | | 22606 | | 740 | | 25 | | 0.19 | 0,11 |
| 1992 | 379128 | -0,82 | 24242 | 7,24 | 751 | 1,49 | 36 | 44 | 0,20 | 0,15 |
| 1993 | 381250 | 0,56 | 30318 | 25,06 | 648 | -13,72 | 43 | 19,44 | 0,17 | 0,14 |
| 1994 | 365663 | -4,09 | 47799 | 57,66 | 160 | -75,31 | 62 | 44,19 | 0,04 | 0,13 |
| 1995 | 409693 | 12,04 | 57743 | 20,8 | 40 | -75 | 80 | 29,03 | 0,01 | 0,14 |
| 1996 | 485595 | 18,53 | 64886 | 12,37 | 52 | 30 | 79 | -1,25 | 0,01 | 0,12 |
| 1997 | 506498 | 4,30 | 77940 | 20,12 | 823 | 1481,73 | 127 | 60,76 | 0,16 | 0,16 |
| 1998 | 483338 | -4,57 | 94214 | 20,88 | 726 | -11,73 | 1889 | 1387,4 | 0,15 | 2,01 |
| 1999 | 536387 | 10,98 | 128486 | 36,38 | 765 | 5,37 | 26012 | 1277,02 | 0,14 | 20,25 |
| 2000 | 553925 | 3,27 | 132585 | 3,19 | 1019 | 33,2 | 25424 | -2,26 | 0,18 | 19,18 |
| 2001 | 722355 | 30,41 | 138522 | 4,48 | 163240 | 15919,63 | 28561 | 12,34 | 22,60 | 20,62 |
| 2002 | 844553 | 16,92 | 157530 | 13,72 | 342745 | 109,96 | 28126 | -1,52 | 40,58 | 17,85 |
| 2003 | 671380 | -20,50 | 172619 | 9,58 | 269029 | -21,51 | 28512 | 1,37 | 40,07 | 16,52 |
| 2004 | 868576 | 29,37 | 173224 | 0,35 | 372032 | 38,29 | 20225 | -29,06 | 42,83 | 11,68 |
| 2005 | 844369 | -2,79 | 208002 | 20,08 | 384006 | 3,22 | 19609 | -3,05 | 45,48 | 9,43 |

Figure 1 shows the percentage of the departmental contribution of Ancash in both commodities which are considered the most representative in the mining sector.

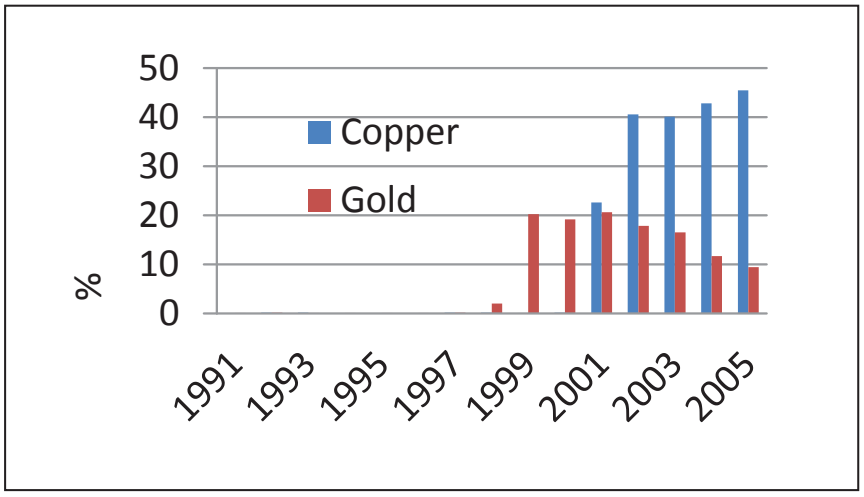


**Figure 1.** Departmental share for Ancash in percentage of the national production of copper and gold in Peru. Source: INEI.

The development of gold and copper production in the Department Ancash is analyzed for the years from 1991 until 2005 in Figure 2.

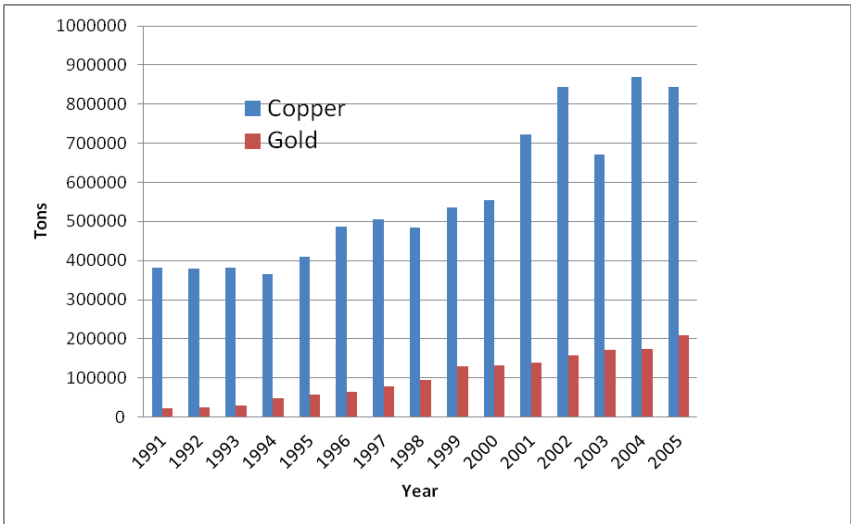


**Figure 2.** Production of gold and copper in Ancash (in tons). Source: INEI.

Additionally, it is profitable to compare the percentage of mining in the Peruvian GDP with the contribution of copper and gold production in the Department Ancash. This comparison is chosen because an analysis showed the correlation of the variables mining GDP for Peru and copper and gold production in Ancash to be significant: the coefficient of correlation for the production of gold (in tons) with the percentage contribution of mining to the Peruvian GDP is equal to 0,80; for the case of copper production (in tons) it is equal to 0,79.

**Table 2.** Porcentual Mining into Peru´s GDP. Copper- Gold production for Ancash. Source INEI

| Year | Mining of GDP (%) | Gold Prod. | Copper Prod. |
|---|---|---|---|
| 1991 | 4,1 | 2,2606 | 38,2277 |
| 1992 | 4,4 | 2,4242 | 37,9128 |
| 1993 | 4,6 | 3,0318 | 38,125 |
| 1994 | 4,7 | 4,7799 | 36,5663 |
| 1995 | 4,5 | 5,7743 | 40,9693 |
| 1996 | 4,3 | 6,4886 | 48,5595 |
| 1997 | 4,3 | 7,794 | 50,6498 |
| 1998 | 4,0 | 9,4214 | 48,3338 |
| 1999 | 4,9 | 12,8486 | 53,6387 |
| 2000 | 5,2 | 13,2585 | 55,3925 |
| 2001 | 4,9 | 13,8522 | 72,2355 |
| 2002 | 5,5 | 15,753 | 84,4553 |
| 2003 | 6,1 | 17,2619 | 67,138 |
| 2004 | 7,7 | 17,3224 | 86,8576 |
| 2005 | 8,8 | 20,8002 | 84,4369 |

Figure 3 shows a summary of the data for these variables from 1991 until 2005.

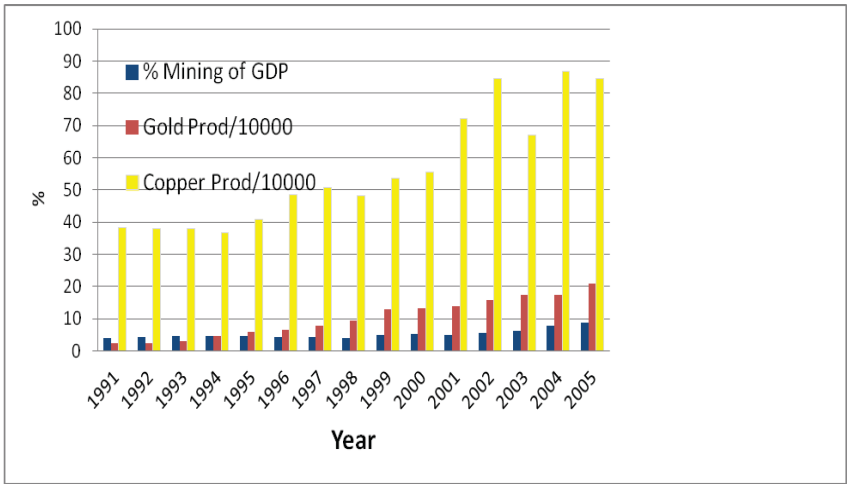


**Figure 3.** Comparison of Mining GDP (Peru) with Copper and Gold Production for Ancash (in tons). Source: INEI.

The analysis of the mining production and the contribution of the Department Ancash to this sector allow us to have an overview of the role of Ancash in the national economy and the dimension of use of its natural resources in mining. It is also paradox that mining represents the first and most important income to households, being a sector which simultaneously increases geographical vulnerability. This is the first of the many studies that are currently in process for each variable of the SVI, the social part of SilVIo.

## 4 CONCLUDING REMARKS

This research is in currently under development and extended through a constant information exchange. In general, with the evolving model we present a composite indicator, called SilVIo, using variables of importance to the local residents in the area of research. Given that some variables are of linguistic nature it is necessary to apply fuzzy dynamic(Gil-Aluja 1990). The weight of the variables is a direct appraisal from the local knowledge which awards the SVI indicator a representation of the population dynamic. This constitutes a quite distinctive characteristic compared to other indicators and it is an expression of an enhanced social and environmental responsibility. In this context, we consider an initial analysis of the mining sector because of the high correlation (0,8) between its share in the national GDP and the mining activity at the departmental level. The way of modelling the expertise and local knowledge of the residents of the Shallap canyon makes this research project a new contribution to the extensive field of modelling human systems.

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