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Analysis of available capitals in agricultural systems in rural communities: the case of Saraguro, Ecuador

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Abstract

This paper presents the application of a new methodology for the analysis and appraisal of available capitals in rural community farming systems in research, technological development and innovation (R&D&Ti) projects. The methodology is based on participatory processes in the appraisal of capitals and includes the following: a) analysis of objectives and classification by capital; b) design of variables and indicators; c) information collection and systemization; d) appraisal of indexes of community capitals; and e) analysis of capital indexes. The analysis was conducted in 19 communities in the Saraguro canton. These communities participated in an R&D&TI project, which lasted for 14 years and is based on the Farming Systems Approach to Research. This application explains, for the first time in this region, the advantages of applying methods for appraising capitals available in community farming systems, considering the different dimensions that should be included in the implementation of the R&D&Ti projects for development. The principal contribution is based on the indexes of capitals and the appraisal that integrates information from the rural communities and their social preferences, using participative techniques in Farming Systems Research and in the processes of evaluation.

Additional key words: community capitals indexes; farming systems; R&D&Ti development projects; rural poverty; social learning; sustainable rural livelihoods.

Resumen

Análisis de los capitales disponibles en los sistemas agrícolas de las comunidades rurales: el caso de Saraguro, Ecuador

Este artículo presenta la aplicación de una nueva metodología para el análisis y la evaluación de los capitales disponibles en la comunidad rural, los sistemas de cultivo, la investigación, el desarrollo tecnológico y la innovación (I+D+i) en los proyectos. La metodología se basa en procesos participativos para la evaluación de los capitales disponibles por las comunidades rurales e incluye, a) el análisis de los objetivos y su clasificación por capital, b) el diseño de las variables e indicadores; c) la recolección de información y su sistematización; d) la valoración de los índices de los capitales, y e) el análisis de los índices por capital. El trabajo se desarrolló en 19 comunidades del cantón Saraguro que participaron en un proyecto de I+D+i que duró 14 años y se basa en el enfoque de sistemas agrícolas. Esta aplicación explica, por primera vez en esta región, las ventajas de la aplicación de métodos de valoración de los capitales disponibles en los sistemas agrícolas de la comunidad incluyen las diferentes dimensiones de la I+D+i para el desarrollo. La principal contribución se basa en la generación de los índices de capitales y su valoración integra información de las comunidades rurales utilizando técnicas participativas de investigación en sistemas agrícolas y procesos de evaluación.

Palabras clave adicionales: aprendizaje social; I+D+i de proyectos de desarrollo, índices de los capitales de la comunidad; medios de vida sostenibles, pobreza rural; sistemas de cultivo.

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Introduction

The United Nations Millennium Development Goals define poverty in economic terms as daily income. The proposed baseline indicator is US$ 2 a day per person (ONU, 2000). However, nothing is said about the level of well-being people can achieve with two dollars a day in each country. For Flora *et al.* (2004), well-being cannot be measured as an amount of money, but rather, in terms of capitals —natural, social, cultural, physical, financial and human *resources or assets*— that can be invested to create new resources and have the potential to improve their quality of life. Recent research in farming systems (León-Velarde *et al.*, 2008) shows that technologies and strategies that link research and development should be based on a) use and conservation of natural resources, b) market-oriented agricultural systems, c) improved postharvest processes, and d) policies that promote commercial relationships at the local, national and regional levels. From this perspective, intensification of agricultural systems based on crop-livestock R&D&Ti should be considered a major basis for development of poor regions as an endogenous process of rural households in response to population increase (Williams *et al.*, 1999). The conceptual framework of Farming Systems Research (Hart, 1982, 2000) is fundamental to achieving development and sustainability of small-holder farming systems, especially in mountainous zones.

Farming Systems Research in Latin America began in the 1970s in the search to adapt new technology and its dissemination to the idiosyncrasies of Latin American farmers (Hart, 1982, 2000). This development research approach emerged as an alternative to other types of research that are reductionist in their approach, an approach that has been demonstrated to be less efficient (Hart, 2000; Quiroz *et al.*, 2000; Barrera *et al.*, 2004a,b; León-Velarde *et al.*, 2008). One exception was the Green Revolution, which, in spite of being reductionist, achieved great impacts in the struggle against poverty. It did not, however, anticipate negative results such as damage to the environment caused by agrochemicals or the enormous amount of energy necessary for this type of agriculture (Mann, 1997).

One of the lessons learned from the application of Farming Systems Research in Latin America was that farmers do not adopt complete technological packages but, rather, only some of their components (Collinson, 2001; Tinsley, 2004). It appears, however, that this lesson is often not considered, and projects that promote technological packages continue to be financed without benefiting small farmers (IFAD, 2001; Tinsley, 2004). Numerous studies give evidence that, in order for these R&D&Ti development projects to be effective, they must be undertaken with an open-minded approach to development (DFID, 1998; Ellis, 1998; Collinson, 2001), encourage broad-based participation (Chambers, 1994; Cazorla *et al.*, 2005) and community capacity building (Simpson *et al.*, 2003; Kirk and Shutte, 2004; Díaz-Puente *et al.*, 2009), and stimulate diversification in agricultural activities (Bhende and Vetkataram, 1994). Other experiences in the Andes eco-region emphasize the importance of optimizing technological components (Barrera *et al.*, 2004b; León-Velarde *et al.*, 2008) as well as the need for a holistic view of the problems of rural communities (Collinson, 2001).

The *sustainable rural livelihoods* approach identifies five principal categories of capital that provide the foundation for livelihoods: social, financial, physical, natural and human. Flora *et al.* (2004) developed the *Community Capitals Approach* and determined that the communities that were successful in supporting sustainable and healthy economic development paid attention to seven types of capital, adding cultural and political capital to the original five. According to these authors, no capital by itself can determine the success of development processes. Thus, it is necessary that all of them exert their effects jointly, through their different interactions.

This paper analyzes the current state in which the capitals are found within the farming systems of the rural communities of Saraguro with the aim of providing a tool for improving the implementation of R&D&Ti projects. The information obtained and the methodology proposed for the analysis of capitals will be of use in the design and implementation of new policies and research projects for the development of agriculture in this and other similar poor regions.

Methodology

Methodology for the analysis of indexes of community capitals

The methodology proposed for evaluating the indexes of community capitals in rural communities can

Abbreviations used: INIAP (Instituto Nacional Autónomo de Investigaciones Agropecuarias, National Institute for Agricultural Research), PCA (principal components analysis), R&D&Ti (Research, Development and Technological Innovation).

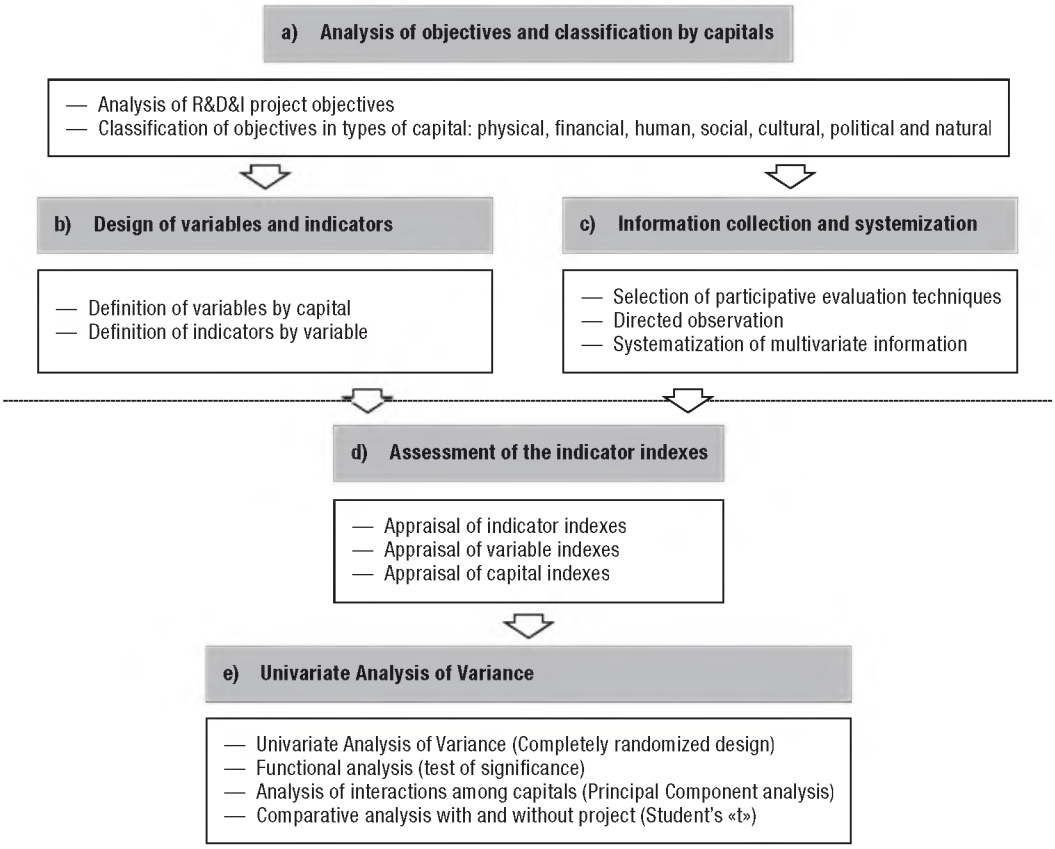

Figure 1. Methodological process proposed for the assessment of capitals available in rural communities.

be seen in Figure 1. The process comprises five phases: (a) analysis of project objectives and their classification in capitals at the disposition of the communities; (b) design of variables and indicators; (c) collection and systemization of information; (d) appraisal of indexes of the capitals, and (e) analysis of results and interactions among the capitals.

a) *Analysis of objectives and their classification by capitals*

The hypothesis proposed for the use of capitals as substantive dimensions of the assessment originates from the argument that the main objectives of the projects are framed within the capitals necessary to achieve sustainable human development (PNUD, 1994), generate *social learning processes* (Cazorla *et al.*, 2005), and empower rural communities (Chambers, 1994; Díaz-Puente *et al.*, 2009). Here, we briefly define each of the seven community capitals which are the foundation for designing the variables and indicators of R&D&Ti projects.

Cultural capital comprises values as well as recognition and celebration of cultural heritage. This capital is the result of the interactions between human beings and their surroundings, thus explaining ways of «knowing» and of «being» and their special way of seeing the world and defining what has value and, moreover, what can change (Bebbington, 1999; Flora *et al.*, 2004).

Financial capital consists of economic resources that are used for investment before being used for consumption (Lorenz, 1999). Financial capital deals with money available in cash or equivalents that allow people to adopt different livelihood strategies (DFID, 1998).

Physical capital is referred as the basic infrastructure that facilitates productive, reproductive and social activities of the community (Flora *et al.*, 2004). DFID (1998) defines physical capital as the production commodities necessary to support livelihoods.

Human capital encompasses aptitudes, knowledge, work capabilities and health that, together, enable populations to undertake different strategies and reach their objectives in terms of livelihoods (DFID, 1998).

The human capital includes education, skills, health, self-esteem, and leadership (Flora *et al.*, 2004).

Natural capital is that from which resources flow and ecosystem services are derived and which are useful in terms of sustainable rural livelihoods (Constanza *et al.*, 1997); includes all of the natural resources in the surroundings that are essential for the ecosystem to function and for the well-being of the people (Flora *et al.*, 2004).

Political capital refers to the ability to deal with coercion and application of laws or ordinances —governability— as well as to participative skills, voicing opinions and influencing decisions that can transform the other capitals (Aigner *et al.*, 2001).

Social capital refers to the interactions, connections, and relationships that unite individuals and communities (Narayan, 1999; Maru *et al.*, 2007). From the perspective of local development there are elements of social capital that contribute to its sustainability (Midgley and Livermore, 1998).

b) *Designing variables and indicators of the capitals*

Parting from the objectives posed by the projects and the existing state of the beneficiary communities, it is necessary to design a set of variables for each of the capitals and indicators for each variable to determine the evolution and outcomes of the projects. The *variables* are measureable characteristics or properties of the community capitals under study, and the *indicators* are the instruments with which to evaluate these characteristics and detect the variation among the rural communities. The variables are complex, and the indicators are their constituent elements (Di Rienzo *et al.*, 2001). Within the definition of each capital, there are important aspects that can be considered possible variables for the assessment process, and these will depend on the objectives the R&D&Ti projects pursue; that is, the variables and indicators of the community capitals are specific to each project.

The *Community Capitals* approach is grounded in three fundamental principles. The first principle is that all of the communities have resources, even rural, isolated or poor communities; when these resources or assets are invested to create new resources, they attain the category of *capital*. Second, to generate well-being in the families, it is necessary to achieve balance among the available community capitals. Finally, the third principle is that all of the capitals be considered equally important for the generation of well-being and sustainable rural livelihoods. Flora *et al.* (2004) mention that positive and negative interactions may occur among the capitals and can contribute to, or harm, the well-being of the family farming systems (externalities). Under these principles, all capitals are assigned equal values. The variables and indicators that enable us to assess the impact of the Saraguro project were selected through analysis of the proposed objectives.

c) *Information collection and systemization*

Once the indicators and variables of the community capitals are defined, in this third phase, the information collection and systemization process is determined. It is important that, when designing the information-collection instruments and techniques, the type of participants, the context and the purpose of the assessment to be carried out be considered in order to satisfy the needs of the evaluation. To collect the information, participative evaluation techniques such as *key informant interviews* (Nirenberg *et al.*, 2005), *Participatory Rural Appraisal* (Chambers, 1994), *Empowerment Evaluation* (Fetterman, 1995), *Directed Observation* (World Bank, 2002) were used. Moreover, it is essential to establish a sample size that allows extrapolation of the results to the stakeholders that may have a relationship with the project (Fuentelsaz-Gallego, 2004).

d) *Appraisal of community capitals indexes*

The information systemized in multivariate databases is used to evaluate and characterize the capitals available in the rural communities participating in the R&D&Ti projects. For analysis of the capitals, an index is constructed for each capital. The indexes are established on the basis of the transformation of the values of each indicator to a proportional value within an interval of 0 to 1. Values are assigned considering the maximum and minimum values registered for each indicator. The maximum value of the indicator is 1 and the minimum 0. The values of the indicators by variable and by capital are then added up, and the sums are also transformed into values in the range of 0 to 1. The matrix structured for calculating the indexes of the variables can be expressed in the following manner:

$$V_x = \begin{bmatrix} J_{11} & J_{12} & \cdots & J_{1n} \\ J_{21} & J_{22} & \cdots & J_{2n} \\ \vdots & \vdots & & \vdots \\ J_{m1} & J_{m2} & \cdots & J_{mn} \end{bmatrix} \quad [1]$$

where V_x is the matrix of the indexes of the variable x, J_{ij} is the index of the variable x in the indicator j corresponding to community i; m is the number of communities under study $i = 1, 2, \ldots m$; and n is the number of indicators under study $j = 1, 2, \ldots n$.

The row vectors of this matrix with n indicators $J_i = (J_{i1}, J_{i2}, \ldots J_{in})$ represent an index in each community, in such a way that the index of the variable x for each community i is obtained using the following equation:

$$X_i = \sum_{j=1}^{n} J_{ij} / n \quad [2]$$

X_i being the variable x in community i; J_{ij} the index of the variable x in the indicator j corresponding to community i and n is the number of indicators under study.

The matrix constructed for calculating the indexes for each community capital can be expressed in the following manner:

$$C_y = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1z} \\ X_{21} & X_{22} & \cdots & X_{2z} \\ \vdots & \vdots & & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mz} \end{bmatrix} \quad [3]$$

where C_y is the matrix of the indexes that correspond to capital y ; X_{iz} is the index of capital y in variable k corresponding to community i; m is the number of communities under study $i = 1, 2, \ldots m$; and z is the number of variables under study $k = 1, 2, \ldots z$.

The row vectors of this matrix with z variables $X_i = (X_{i1}, X_{i2}, \ldots X_{iz})$ represent one index in each community, in such a way that the index of capital y for each community i is obtained with the following expression:

$$C_{yi} = \sum_{k=1}^{z} X_{ik} / z \quad [4]$$

where C_{yi} is the index of capital y in community i; X_{ik} the index of capital i in the variable k that corresponds to community i, and Z is the number of variables under study.

Based on the definitions given in this section, Table 1 shows the construction of the indexes of capitals by community; these indexes are based on the indicators and variables established for each capital.

Concordant with the three principles suggested by Flora *et al.* (2004), the same weight is given to the indicators and variables that are considered in the analysis of the community capitals. That is, *communities that are successful and have attained sustainable and healthy economic development pay attention to seven types of capital: human, social, natural, physical financial, cultural and political, and their interrelationships contribute positively or negatively to increasing the rest of the capitals, so that when one type of capital is maximized with respect to the other capitals, other assets are de-capitalized, and the economy, the environment or social equity can become compromised.* Positive interactions, or synergies, among capitals

Table 1. Construction of capital indexes by community

Communitary	Variable X_1				Variable X_2				Capital C_1
	Indicators			Index X_1	Indicators			Index X_2	Index C_1
	j_1	...	j_n		k_1	...	k_n		
i_1	J_{11}	...	J_{1n}	$X_{11} = \sum_{i=1}^{n} J_{1i} / n$	K_{11}	...	K_{1n}	$X_{21} = \sum_{k=1}^{n} K_{1k} / n$	$C_{11} = \sum_{j=1}^{z} X_{j1} / z$
i_2	J_{21}	...	J_{2n}	$X_{12} = \sum_{i=1}^{n} J_{2i} / n$	K_{21}	...	K_{2n}	$X_{22} = \sum_{k=1}^{n} K_{2k} / n$	$C_{12} = \sum_{j=1}^{z} X_{j2} / z$
...	...	...	...	...	...	...	...	...	...
i_m	J_{m1}	...	J_{mn}	$X_{1m} = \sum_{i=1}^{n} J_{mi} / n$	K_{m1}	...	K_{mn}	$X_{2m} = \sum_{k=1}^{n} K_{mk} / n$	$C_{1m} = \sum_{j=1}^{z} X_{jm} / z$

z: number of variable determined for each capital under study.

favor *Sustainable Human Development*, understood as *development that not only generates economic growth but also distributes benefits equitably, regenerates the environment instead of destroying it, and empowers people instead of marginalizing them* (PNUD, 1994).

e) *Analysis of capital indexes*

Once the indexes by capital and community are obtained (Table 1), the values are subjected to a Univariate Analysis of Variance (ANOVA), using a Completely Randomized Design (Little and Hills, 1979; Stevens, 2002), where communities or families constitute treatments. The statistical model is:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij} \quad [5]$$

where Y_{ij} is the value of the indexes by community or family; μ is the general average of each index by capital; τ_i is the effect of the treatments and, ε_{ij} is the experimental error.

The null hypothesis H_0: $\mu_1 = \mu_2 = \mu_3 = ... = \mu_n$, is that the value of the indexes of the community's capitals are equal, which would indicate that the impact of the project was homogeneous for all of the communities. In this case, all of the families or communities would have had the same opportunities for success during the evolution of the project. In contrast, the alternative hypothesis H_A: $\mu_1 \neq ... \neq \mu_n$, that there are differences among the values of the average indexes of two communities, would imply that the project had differential impacts on the communities or families.

To differentiate the capitals of the participating families or communities in function of their availability, it is necessary to carry out a functional analysis using any of the tests of significance esteemed suitable. With regard to the analysis of interactions among capitals a Principal Components Analysis (PCA) is suggested (Gabriel, 1971). This PCA is a standard tool in modern data analysis in diverse fields because it is a simple, non-parametric method for extracting relevant information from confusing data sets (Jolliffe, 2002). This analysis reveals the interdependence among measured variables and provides an optimum graphic representation of data variability from a table of *n* observations and *p* columns or variables. The PCA seeks to find, with minimum loss of information, a new set of non-correlated variables (Principal Components-PC) that explain the structure of variation in the rows of the table of data. The result of this analysis is the representation of all of the variables on a bi-dimensional plane (biplot) that explains the interrelationships between communities or families and the capitals as well as the maximum variability and interdependence among cases variables by constructing artificial axes (PC). On the biplot, the angle between the vectors of the capitals characterizes the type of interaction that exists between them. If the vectors form acute angles, there is a maximum positive interrelationship between the two capitals. If the vectors form a straight line, there is no interrelationship between them. When the vectors form obtuse angles, the type of interrelation between the capitals is negative. The methodology also proposes a comparative analysis between the community capitals indexes «with» project and those «without» project intervention to determine the effects and impacts of the projects. It is suggested that this comparative analysis be done with the paired *Student's t* Test:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S_{\bar{d}}} \quad [6]$$

where $\bar{x}_1$ is the average of the indexes by capital with the implementation of the project; $\bar{x}_2$ is the average of the indexes per capital without implementation of the project, and $S_{\bar{d}}$ is the standard error of the mean of the differences with and without project.

The null hypothesis, H_0: $\mu_1 = \mu_2$, is that the values of the community capitals indexes «with» and «without» project implementation are similar, while the alternative hypothesis, H_A: $\mu_1 \neq \mu_2$, states that the values of the community capitals indexes «with» and «without» implementation of the project are different.

Application of the R&D&TI project methodology in Saraguro

This section describes how the proposed methodology was applied in one of the poorest mountain regions of Ecuador, the Saraguro canton. Since 1995, R&D&Ti actions based on the Farming Systems Research approach have been carried out in the 19 communities of Saraguro.

The study area (Fig. 2) comprises 11 village settlements of the Saraguro canton. This area is located in the northern part of the Loja province, Ecuador; it has an area of 1,080 km^2, and its geographic coordinates are 3°50'-3°50' S and 79°13'-79°30' W. Climate types represented in the area are wet low Tropical montane forests, very wet Tropical montane forests, and dry low

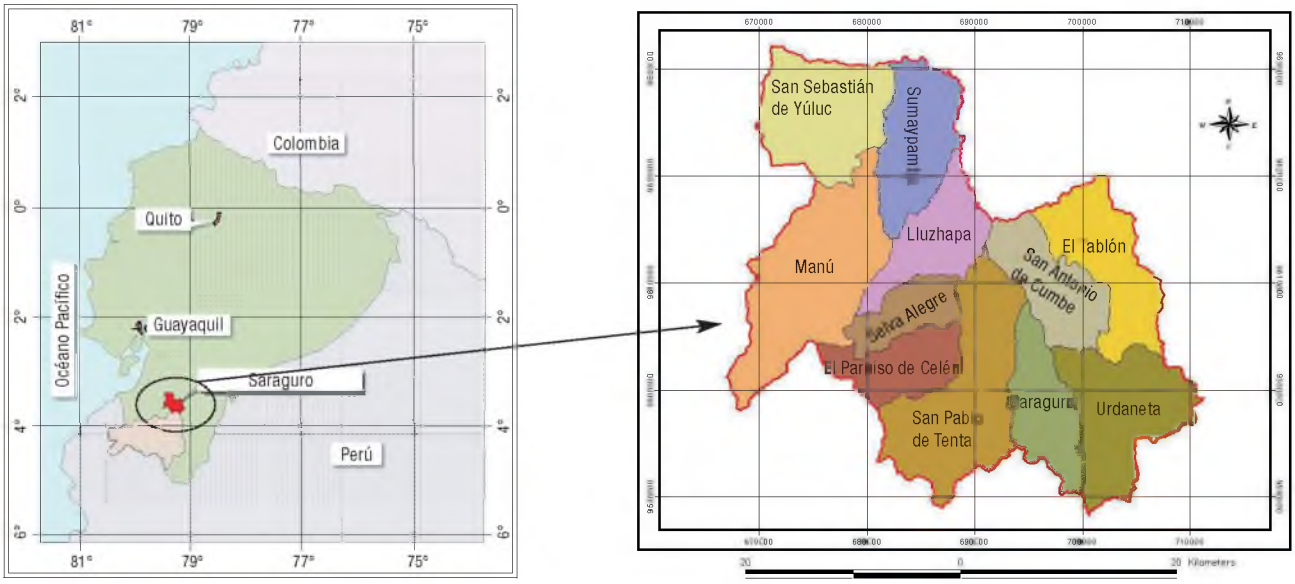

Figure 2. R&D&Ti project area of influence in the Saraguro canton, Loja Province, Ecuador.

Tropical montane forests (SIGARO, 2008). Saraguro is considered one of the 20 poorest cantons of Ecuador, with a rural poverty rate of 93%. The total population is 31,000, 49% men and 51% women; 46% belong to the Saraguro indigenous ethnic group, while 54% are mestizos. Of those that are of working age (20,460), 52% make up the economically active population. More than 50% of the rural families' income, whose yearly average is US$ 397, is earned in wage (off-farm) work, which is scarce, seasonal and low-paying. The rate of permanent migration and abandonment of the countryside is more than 27% (INEC, 2001).

In Saraguro, 95% of the farmers own 0.2 to 9 ha, 2.87 ha on average per family, while the other 5% have holdings of more than 10 ha. The agricultural systems are subsistence farms based mainly on crops such as barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), maize (*Zea mays*), potatoes (*Solanum tuberosum*) and peas (*Pisum sativum*), and small-scale dairy production, all of which have very low average yields, lower than the agroclimatic potential of the region. This is due to the use of little or no modern technology. Yields of maize, wheat, barley and peas do not surpass 0.8 t ha^{-1} and potato yields are 4.5 t ha^{-1} or less (Vivar *et al.*, 2008).

Phases of the R&D&Ti Saraguro project

To contribute to the solution of the problems of the Saraguro canton, since 1995, the Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA Spain), through the Consultative Group on International Agricultural Research (CGIAR) and in close cooperation with the International Potato Center (CIP) and the International Maize and Wheat Improvement Center (CIMMYT), has supported the implementation of R&D&Ti agricultural actions based on the *Farming Systems Research* approach (Hart, 2000). The actions for improving agricultural systems and the Saraguro communities' capitals were executed in three phases over a period of 14 years, beginning in 1995 and ending in 2008. These were implemented through an R&D&Ti project with the active participation of 19 communities. This project permanently aimed to achieve specific objectives of development through the generation of new processes, new products and new technologies, which constitute innovations capable of promoting improvement in the communities' capitals.

Although the overall objectives were maintained throughout the project, the scale, the approach and the context (Table 2) evolved in each of the project phases as a consequence of the particular experiences and interests of the rural communities involved. In the first phase (1995-2000), the R&D&Ti project worked with the INIAP Chuquipata Experimental Station and implemented actions in the farmers' plots. This mechanism was framed within a reductionist approach that took into account only the crop component and, of this, only cereals (wheat and barley). In this initial phase, the participation of the farmers in technological

Table 2. Analysis of the three phases of implementation of the R&D&TI Saraguro projeto. Loja Province, Ecuador

	Fist phase (1995-2000)	Second phase (2001-2003)	Third phase (2004-2008)
Scale	Experimental station Farmers' plots	Experimental station Farmers' plots	Production systems Experimental station
Approach	Reductionist	Reductionist Farming systems	Farming systems
Context	Production Productivity	Optimization of farming systems Technological sustainability Productive diversification	Sustainability of farming systems
Participation of farmers	Not relevant	More farmer involvement	Active participation of farmers

development was not relevant for the project promoters and the principal objective was to generate greater production by increasing yields in the farming systems.

Up to the middle of the second phase (2001-2003), the R&D&Ti project maintained the characteristics of the first phase actions. As of 2002, however, the project advocated diversification and complementary activities, giving examples of the multiple possibilities of Saraguro farming systems. This diversified and complementary range of products was driven by greater involvement of the farmers who were those that decided what to do considering their own benefit. At the end of 2003, the project channeled actions toward work in the farming systems. With the *Systems Approach*, work began to orient actions toward optimization of the agricultural systems, sustainability, alternative technologies and diversification of activities, posing the idea that production was not the most important element.

In the third phase (2004-2008), the project carried out mass dissemination of agricultural systems management, in which *Farming Systems Research* enabled the use of different procedures that complemented each other to achieve sustainability, parting from the capitals available to the community. Participatory Research, Farmers Field Schools, the gender approach, institutional and political alliances, preparation of leaders, empowering communities through evaluation, among others, were strengthened, generating synergies among the actors.

Methodology of analysis

Selection of the variables and indicators of the R&D&Ti project was based on the objectives proposed by the project in its different phases: a) to offer farmers a set of technological options to enable them to improve the use of resources and productivity of their farming systems; b) to increase the availability of improved seed of varieties of the main food crops and forages with productive and market potential; c) to promote market access of local products; d) to diversify farm production in order to improve the families' diet; and e) human capital building to improve self-sustainability of the farming systems.

These project objectives (Phase A of the methodological process) are related to the communities' physical, human and financial capitals, with little concern for the state and availability of social, political, cultural or natural capital. In spite of the awareness that this was lacking in the objectives, during the process of analysis and evolution of the capitals, the communities' seven types of capital were included because they were seen to have had an impact. In the design of the variables and indicators of the capitals (Phase B), 18 variables and 80 indicators were considered (Table 3).

For information collection (Phase C), four techniques were used: key informant interviews, participatory rural appraisal, empowerment evaluation, and directed observation. The key informants were project personnel and 19 community leaders. Participatory Rural Appraisal was carried out in workshops in which 19 representatives from eight communities (Mater, Lluzhapa, Gañil, Turupamba, Tenta, Cañicapac, La Papaya and El Sauce) participated. Two workshops were conducted with focal groups using the technique of Empowerment Evaluation (Fetterman, 1995), one with seven local actors and the other with 12 representatives from the communities. Directed Observation confirmed and complemented the information compiled in the interviews.

Table 3. Variables and indicators of capitals available in the communities of Saraguro, Loja Province, Ecuador

Capitals	Varibles	Indicators
Physical	Availability of technology	1. Number of farmers who introduced new crops. 2. Number of farmers who process their production. 3. Number of farmers who use environment-friendly practices (integrated crop management in potatoes and fruit trees). 4. Number of farmers who have adopted measures to improve quality of their produce. 5. Number of farmers who plant pasture in contour strips. 6. Number of farmers who rotate crops (grass, potatoes, cereals). 7. Number of farmers who incorporate organic matter and plow crop residues into the soil. 8. Number of hectares in which erosion control has been implemented. 9. Number of farmers who produce guinea pigs by using well-system. 10. Number of farmers who produce milk with improved pastures. 11. Number of farmers who have adopted new techniques for production of dairy products.
	Availability of equipment and tools	1. Number of communities that have grain silos. 2. Number of bean and maize planters in the region.
	Availability of services	1. Presence of a technical assistance service. 2. Number of farmers who have received technical assistance. 3. Number of times technician visited the pilot farms.
Human	Training and dissemination	1. Percent learning achievement in training events.
	Labor	1. Number of jobs created in the areas of postharvest and agroindustry. 2. Number of young farmers (up to 35 years) who work. 3. Productive activities in which women participate. 4. Number of family members who have emigrated permanently from the zone in the last 10 years. 5. Number of family members who have emigrated temporarily in the last 10 years. 6. Number of destinations of permanent emigration. 7. Number of destinations of temporary emigration. 8. Number of family members who participate in farm production. 9. Number of workdays of contracted labor needed for the activities. 10. Number of off-farm workdays. 11. Number of families who arrived in the region in the last 10 years.
	Health and nutrition	1. Number of vegetable (species) produced for home consumption.
Financial	Income generation	1. Number of activities that provide economic income. 2. Main economic activity. 3. Number of farmers who use supplementary irrigation. 4. Number of farmers who harvest two crops of cereal a year. 5. Number of inhabitants who receive irrigation water from the reservoirs. 6. Number of farmers who use postharvest management techniques. 7. Number of farmers who sell their farm products. 8. Price of the products they sell. 9. Number of families who have increased their incomes due to the implementation of project activities.
	Access to markets	1. Number of markets where they sell. 2. Number of farmers who sell direct. 3. Number of farmers who sell quality products.
	Mechanisms of negotiation	1. Number of sales agreements. 2. Forms of payment. 3. Agreements referring to quality.

Table 3 (cont.). Variables and indicators of capitals available in the communities of Saraguro, Loja Province, Ecuador

Capitals	Varibles	Indicators
	Access to financing	1. Number of farmers who have access to credit, either formal (with banks) or informal (moneylender). 2. Number of farmers who receive loans in species through the revolving fund. 3. Number of farmers who receive cash loans through the revolving fund. 4. Number of headings in which loans from the revolving fund are invested. 5. Interest rates for loans from the revolving fund. 6. Perception of the conditions of loans granted through the revolving fund.
Cultural	Modifications in customary production practices	1. Number of traditional regional crops. 2. Number of non-traditional crops introduced through the Project. 3. Number of traditional production practices. 4. Number of alternative practices introduced through the Project.
	Modifications in dietary customs	1. Number of staples in the local diet. 2. Traditional forms of consuming staples in the local diet. 3. Number of vegetable (species) consumed. 4. Alternative forms of consuming vegetables introduced by the project through family gardens. 5. Number of family gardens currently kept. 6. Number of vegetable (species) grown in family gardens.
Political	Community leadership action	1. Number of leaders participating actively in the project. 2. Number of female leaders participating actively in the project. 3. Number of male leaders participating actively in the project. 4. Number of young leaders participating actively in the project. 5. Positive or negative recognition of leaders' actions in the project.
	Organisms present in the region	1. Number of agreements established between local government and community within project activities. 2. Number of commitments to communities fulfilled by governments within project activities.
	Access to power	1. Number of leaders who have occupied a position of responsibility in local government. 2. Number of projects undertaken through community leader action. 3. Incidence [of influence] in decision-making at the local government level.
Social	Social networks	1. Number of community organizations present in the project area of influence. 2. Number of community organizations with large representation (socially recognized). 3. Number of groups still organized and functioning.
	Institutionalism	1. Norms of behavior and action that regulate the participation of community organization members. 2. Norms of behavior and action that regulate the participation of work groups. 3. Norms of behavior and action that regulate the participation of administrators within the project framework.
Natural	Interventions for improving natural capital	1. Number of soil conservation practices implemented through the project. 2. Number of good water use practices implemented through the project. 3. Number of sources of natural resources that are communal property. 4. Number of environment-friendly practices maintained in community production activities.

The sample size established for gathering information was eight communities, defined with the following formula (Sukhatme, 1953):

$$n = \frac{\frac{t^2(\alpha)}{\varepsilon^2} x \frac{S^2}{\bar{x}_N^2}}{1 + \frac{1}{N} x \frac{t^2(\alpha)}{\varepsilon^2} x \frac{S^2}{\bar{x}_N^2}} \quad [7]$$

where t is the tabular value of *Student's* «*t*» at 95%; ε = the permissible error at 15%; S^2 = mean square of the population, 0.35; $\bar{x}_N$ = mean of the population's maize production, which was 2.10 t ha^{-1} per family; N = number of communities participating in the project (in this case, 19); and n = sample size, which was eight communities.

Once the values of the indexes per capital and per community were obtained (Phase C), in the last phase of the process (Phase D) they were analyzed using a univariate analysis of variance (ANOVA), a functional analysis, an analysis of interactions, and a «with» *vs* «without» project comparative analysis. The univariate analysis of variance was done using a completely randomized design in which the communities were treatments. To separate averages, the Duncan Multiple Range was used with $\alpha = 5\%$ error. The analysis of interactions among capitals was done using the *Principal Components Analysis*, and the comparative analysis of the capitals *with* and *without* project was based on *Student's* «*t*». The data corresponding to the intervention of the project are those compiled for this study; however, the data related to the non-intervention of the project are based on the study of Barrera *et al.* (2004c), who report information on farmers who did not participate in the project. The same analysis was conducted with information on yields of the main farm products recorded by project technicians in their field books from 1995 to 2008 (Barrera *et al.*, 2004c; Vivar *et al.*, 2008).

For each of the indicators, variables and capitals shown in Table 3, the values of the respective indexes is calculated for each of the communities involved in the Project (Table 4). As previously indicated, the values obtained fall within the interval of 1 (maximum value of the indicator, 100%) and 0 (minimum value, 0%).

For example, to calculate the *index of physical capital*, the indicators of the three variables «availability of technology», «availability of equipment» and «availability of services» are determined. To calculate, in each of the communities, the indicator «number of farmers who introduced new crops», the value would be equal to 1 in the communities in which all (100%) of the farmers have adopted new crops, while it would be 0.5 when 50% of the farmers have introduced new crops and zero in communities in which no one (0%) introduced new crops. In the same way, in each of the communities, values are calculated for each of the 11 indicators of the variable «availability of technology». The resulting value for this variable is obtained by averaging the 11 indicator values. The same procedure is used to calculate the other two variables (availability of equipment and tools, availability of services). After

Table 4. Indexes of capitals available to the communities participating in the R&D&TI Saraguro Projects. Loja Province, Ecuador

Community	Family well-being index						
	Physical	Financial	Human	Cultural	Social	Political	Natural
Mater	0.46^{ab}	0.58^{a}	0.59^{b}	0.60^{bc}	0.73^{a}	0.56^{bcd}	0.74^{a}
Lluzhapa	0.30^{cd}	0.58^{a}	0.55^{bc}	0.64^{ab}	0.76^{a}	0.57^{bc}	0.74^{a}
Gañil	0.51^{a}	0.56^{a}	0.41^{d}	0.63^{abc}	0.64^{b}	0.45^{de}	0.54^{b}
Turupamba	0.33^{cd}	0.56^{a}	0.74^{a}	0.72^{a}	0.73^{a}	0.60^{b}	0.54^{b}
Tenta	0.39^{bc}	0.57^{a}	0.37^{d}	0.69^{a}	0.56^{c}	0.72^{a}	0.80^{a}
Cañicapac	0.29^{d}	0.55^{a}	0.42^{cd}	0.69^{a}	0.63^{b}	0.66^{ab}	0.47^{b}
La Papaya	0.30^{cd}	0.51^{a}	0.66^{ab}	0.55^{cd}	0.50^{d}	0.43^{e}	0.27^{c}
El Sauce	0.17^{e}	0.26^{b}	0.45^{cd}	0.50^{d}	0.50^{d}	0.46^{cde}	0.21^{c}
$\bar{X}_g$	0.35	0.53	0.52	0.63	0.64	0.56	0.53
CV	13.10	11.64	12.11	6.42	3.58	9.37	15.14
P	0.0001**	0.0037**	0.0003**	0.0013**	0.0001**	0.0008**	0.0001**

Different letters indicate significant differences ($p \leq 0.05$). **Highly significant differences ($p \leq 0.01$).

calculating these variables, their values are averaged to obtain the value of the *index of physical capital* for each of the communities.

Results and discussion

Results of the analysis of capitals by community

With the application of the methodology proposed for the analysis of available capitals, it is demonstrated that the communities have physical, financial, human, political, cultural, social and natural capitals (Table 4), differentially, as the product of the different combinations of the components of the farming systems in Saraguro. This confirms the coexistence of different farming systems in the extremely poor mountainous areas, which have been previously described (Barrera *et al.*, 2004b; Pender, 2004; León-Velarde *et al.*, 2008). Flora *et al.* (2004) coincides, stating that any community, even the poorest and most isolated, have capitals that can potentially generate well-being and sustainable rural livelihoods.

One group of communities (Mater, Lluzhapa, Gañil, Turupamba, Tenta and Cañicapac) has better living conditions in terms of availability of capitals, mainly physical, financial and human. Physical capital, which refers to the technologies that farmers have adopted, has promoted uniformity in the manner of cultivating in the farming systems. The new technologies have positive implications for their development, level of intensification, and their possibilities of taking advantage of the growing demand for agricultural products (Batz *et al.*, 1999; Adesina *et al.*, 2000).

Farmers' attitudes toward the new technologies are swayed by the resources available to them (Somda *et al.*, 2005), and consequently, promoting adoption of technologies by poor farmers, because of the financial and resource barriers, is very difficult (Batz *et al.*, 1999). In the communities of Saraguro, this barrier was overcome with a revolving fund of approximately US$ 300,000 over a 13 year period beginning in 1996. This fund was established to grant loans in species (seed, fertilizers and other inputs) that improved the financial capital of these communities; the incomes of the 3,048 families of Saraguro increased from US$ 1.2 day^{-1} in 1995 to US$ 3 day^{-1} in 2008 due to higher productivity per unit of area (Table 5).

From the perspective of farming systems, those of Saraguro have been able to evolve and adapt to new socio-economic and market circumstances of farm products, such as maize, barley, wheat, potato and milk (Pagiola, 1996). Increased productivity intensified crop production, mainly cereals, so that farmers were motivated to refrain from expanding cropland toward the high areas where moors prevail as a buffer zone; in this way it contributed to the sustainability of the communities' natural capital (Algensen and Kaimowitz, 2001).

Analysis of the capitals indicates that there are still very poor communities whose families live with very low daily incomes. If these communities (La Papaya and El Sauce) do not continue the actions undertaken with the rest of the communities, they could be very vulnerable to adverse economic and environmental conditions that might occur in the future. The very low indexes of their physical and financial capital do not permit intensification of the activities of the crops and livestock components. This crop and livestock compo-

Table 5. Averages and percentages of increase in yields of several crops, with and without intervention of the R&D&TI Saraguro Project. Loja Province, Ecuador

Crop	No. plots	Average yield (ha^{-1})		Student's «t»	Percent increase
		Without project	With project		
Maize/beans	60	800	1,600	57.85**	100
Maize	80	850	2,100	99.49**	147
Wheat	108	750	2,700	151.47**	260
Barley	108	700	2,800	163.12**	300
Potatoes	55	4,500	7,500	91.35**	67
Peas	35	600	900	86.26**	50
Beans	28	600	1,200	30.90**	100

Data obtained and evaluated in farmers' plots. ** Highly significant differences ($p \leq 0.01$).

nents of the farming systems of Saraguro played very important, but different, roles in the context of sustainable rural livelihood. Farm products were used to improve human (availability of food), cultural (new forms of consuming the products) and financial (higher incomes) capitals, while livestock promoted only human capital, through the families' consumption of milk. Most of the costs, originating from the use of technology, and benefits (providing the basis of human nutrition and additional incomes) are attributed to the crop component, indicating its importance in sustainable rural livelihood strategies that can contribute to reducing poverty in these communities (Bhende and Vetkataram, 1994; DFID, 1998; IFAD, 2001).

The alternative technologies adopted by the farmers promoted greater involvement of family members in productive activities. This can be understood as a way considered by households to relieve poverty, reduce outmigration to the cities and other countries, and increase non-farm opportunities such as forming small groups or organizations to set up small business, which in turn increased the communities' social capital.

Farmer training —through courses, workshops, field trips, observation tours, and fairs— reached most of the farmers and their families and has been a fundamental instrument in persuading farmers to adopt new simple technology. Farmer training, promoting the communities' human capital, has been named by previous studies (Nigel and Michael, 2000; Mauceri *et al.*, 2007; Hashemi *et al.*, 2008) as an important prompter in technology adoption; that is, a higher level of knowledge gained by the farmers can promote better incomes and greater capacity to adopt new technology.

Technical assistance to the farmers is another of the factors that contributed to technology adoption, as occurred in the province of Carchi, Ecuador (Mauceri *et al.*, 2007), where technical assistance played an important role in promoting new technologies. This support, promoting physical capital, was fundamental in the region where there are no extension services and pertinent information is not accessible.

The communities' political capital increased because of the participation of farmers and their families in all of the development processes. Becoming involved in the actions from the initial stages, they became the predominant force in improving their own quality of life. Young women and men were represented in their communities and took a fundamental part in advancing development. In this aspect, it was observed that women were well-represented in political decision-making, an uncommon occurrence in rural communities (Cárdenas *et al.*, 2001; Sayadi and Calatrava-Requena, 2008).

Analysis of interactions among capitals

From the results of the analysis of interactions among capitals, it can be observed (Fig. 3) that there are positive interactions among political, cultural, natural, physical, financial and social capitals. This means that within this group, improvement (investment) in one will generate positive impacts, or positive externalities, on the rest. This could be the key point in generating sustainable rural livelihoods. Investing in improving and conserving natural capital and in strengthening political and cultural capital could generate positive externalities in financial capital, whereby families' well-being is improved.

On the other hand, human capital has a negative interrelationship with natural, cultural and political capital. This is evident, for example, in the communities of La Papaya and El Sauce, where the farmers assert that they have received support from the project in the area of training in organization, leadership, establishing gardens and nutrition. In spite of all these activities, they have not improved their capitals or living conditions as they expected. This could indicate that a different strategy or mechanism of intervention is required.

Comparative analysis of capitals with project against those without project

Figure 4 shows the results of the comparison of values of capitals *with* the implementation of the R&D&Ti Saraguro project against those *without* the project. The results clearly show the achievements obtained in all of the capitals by means of the R&D&Ti actions benefiting the rural communities. Two of the three capitals on which the project was initially based —financial (231%) and human (173%)— are those that had the highest rates of increase. Physical capital had an increment of 105%; *without* implementation of the project the index was 0.17, while *with* project actions the index rose to 0.35. This increment in the values of physical capital is due to the investments in technology, equipment, tools and services. Undoubtedly, acquiring technology, especially agricultural technology, was the main element that won credibility among the families

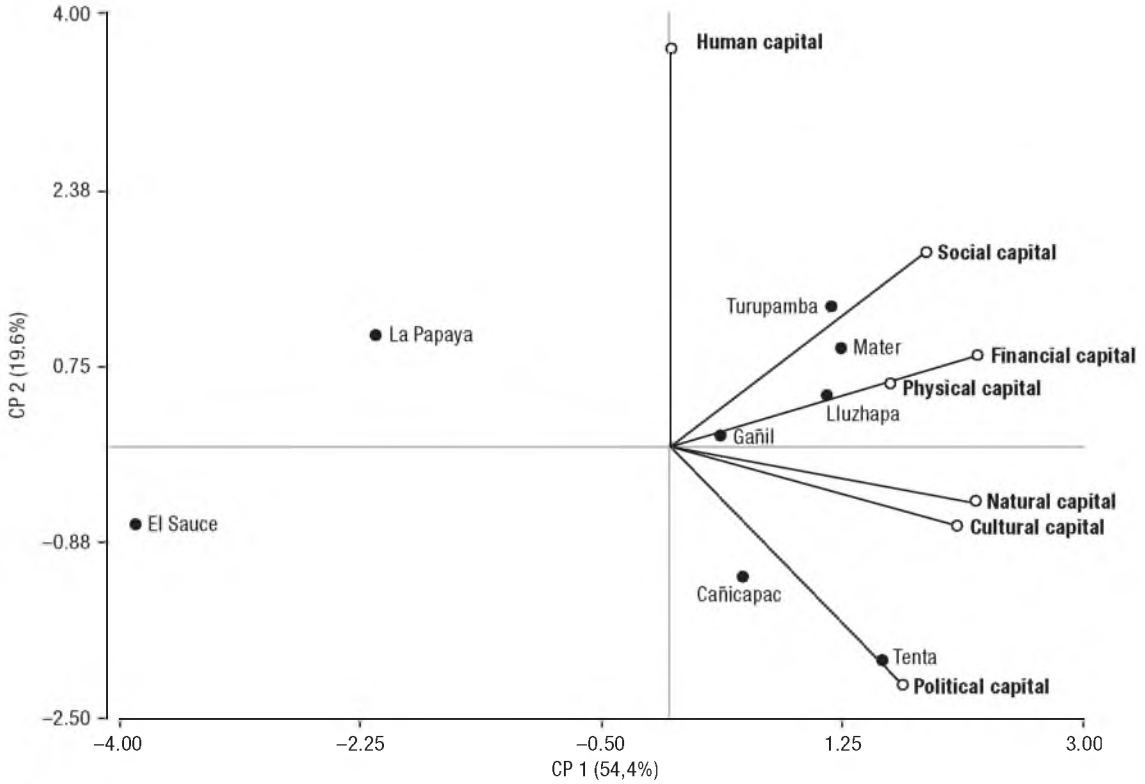

Figure 3. Principal components of the capitals available in the communities participating in the R&D&TI Saraguro Project. Loja Province, Ecuador.

for the project and permitted rapid adoption. Currently, at least 3,048 families implement technological alternatives that promote productivity and sustainability of their farming systems.

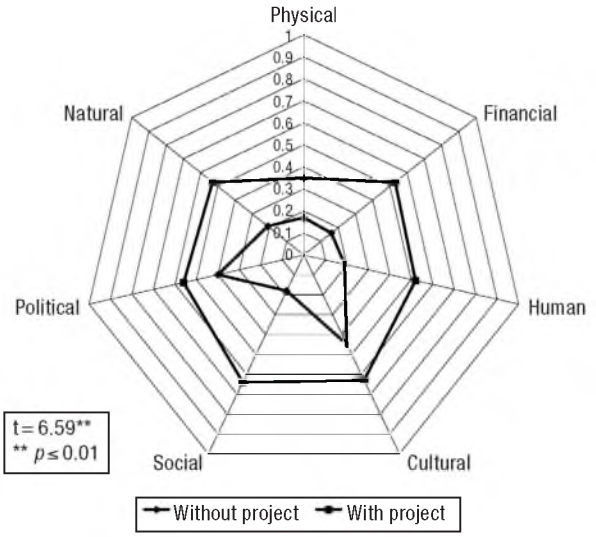

Figure 4. Capitals available in the Saraguro communities, with and without implementation of the R&D&TI Project. Loja Province, Ecuador.

Social capital had the largest increase (255%), achieving an index of 0.64 *with* the project actions compared with an index of 0.18 *without* implementation of the project. This increase is sustained in the social networks and in institutionalism. Through social networking several work groups were created; outstanding among these are those that tend family vegetable gardens, those that raise small animal species such as guinea pigs, and those that administer community savings and loan funds. A relevant point in terms of this social capital is the consolidation of institutionalism among and within the communities. All of the actors show respect, consideration and commitment to joining their efforts in carrying out project activities to obtain the benefits they now have.

On the other extreme, comparing the index *without* implementation of the project (0.40) with that *with* the project (0.56), the capital that had the smallest increment (40%) was political capital. In terms of this capital, one aspect considered relevant in the analysis was that of leadership. Preparation and training of leaders —90 leaders in 19 rural communities— is one of the key elements of the R&D&Ti Saraguro project, requiring leaders who, even at the expense of their own

personal benefit, will always facilitate the communities' development processes.

Conclusions and recommendations

R&D&Ti projects are oriented toward the consolidation of capitals to generate family well-being and sustainable rural livelihoods, and therefore, it is necessary to have a balance among the available capitals. Appraisal of available capitals in the farming systems of rural communities, taking into account their different dimensions, leads to implementation of rural development projects with a broader scope. The proposed methodology, unlike approaches that focus on sectors, makes it possible to relate the objectives of the R&D&Ti projects to the capitals the communities have at their disposal. The main contribution of the methodology lies in the capital indexes and assessment of community capitals that integrate information of the rural communities and their social preferences.

The methodology can be used in a broad diversity of R&D&Ti projects for rural communities, and its application demonstrates that the capitals of their farming systems can be quantified and converted into a tool to aid in improving the quality of the innovations, transparency in the use of public funds, and democratic discussions, which contribute greater knowledge, social learning and understanding of the effects of R&D&Ti projects. The methodology provides information by capital and community as well as among communities, facilitating the prioritization of actions and timely decision-making. The methodology is grounded in the objectives of the R&D&Ti projects, and thus the process of designing variables and indicators are specific for each intervention. In this way, the methodology and results obtained become tools for political decision-making and investment for sustainable rural R&D&Ti projects.

Implementing the Farming Systems Approach to Research in Saraguro project, as a methodological tool for analyzing reality of the production systems in an integrated form, potentiated the capitals of the communities. Physical, human and financial capitals, considered in the objectives of the three phases of the project, generated impacts on cultural, political, social, and natural capitals. Now, the families of Saraguro can earn US$ 3 day^{-1} $family^{-1}$, compared with US$ 1.2 they lived on before the R&D&Ti Saraguro project was implemented in 1995.

The approaches used in the implementation and evaluation of this R&D&Ti project have proved to be efficient and should be considered in the design and implementation of agricultural policies aimed to promote development of poor communities.

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