

Article

Towards decision making for green projects assessment and prioritization, integration between system dynamics and participatory modelling

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Abstract: This research article presents the integration of participatory modeling and system dynamics as a novel methodology for the consolidation of social dynamic models for the subsequent evaluation and prioritization of green projects in Colombian post-conflict communities. In the first instance, through participatory work carried out along with the community, it was possible to identify, evaluate and systematize citizen factors in relation to the problems and needs of the region. Second, based on the results obtained, to calibrate a simulation model based on system dynamics that facilitates decision making with regard to the evaluation of green projects. The proposed methodology leads to the conclusion that, with the participation of the community and with a model based on the dynamics of variables such as supply and demand for natural resources of water and land, it is possible to warn decision makers about the variables that can lead to the maximization of investments and thus prioritize and select the most appropriate environmental, social or economic initiatives, that certainly meet the needs or expectations of the involved community. In the future, the model could be used to facilitate the management, administration and control of water and land resources by creating alerts called reserve margins.

Keywords: Participation; community; systems dynamics; sustainable development; decision making.

1. Introduction

Citizen participation has gained significant importance since the last decade of the last century. Although it has always been recognized as the fundamental pillar of democracy, its power and application are limited, especially in low-income communities, racial minorities and indigenous groups that see participation degrade to their lowest levels of indoctrination and manipulation [1].

Currently, the gap between theory and reality remains wide, but since the end of the 20th century, citizen participation has begun a process of resignification by combining approaches and methods that have evolved to allow communities to express, share and analyze their needs and problems, so that through their self-knowledge they can propose, plan and act, and thus improve their living conditions. Surveys conducted by Chambers [2] show that the power and popularity of Participatory Rural Appraisal (PRA) are in part due to the unexpected analytical skills of local people when they are capitalized through a relaxed and trusting relationship with external facilitators.

For its part, Colombia has not been oblivious to this process and the post-conflict framework has become the ideal setting for the implementation of participatory actions. This is how communities that were affected by the conflict have embarked on new forms of development that provide them with a better quality of life and the non-recurrence of violence. This is the case of vereda El Pesebre, a rural area in the municipality of Tame in the department of Arauca, region affected by armed conflict between 2000 and 2010, where various initiatives have been taken to promote its economic and social development on the basis of associativity and community cohesion, which has enabled it

to become visible to governmental and international institutions that have offered their support for the consolidation of their productive activities.

In this sense, this research exposes the use of Participatory Rural Appraisal (PRA) as a tool for social learning and community knowledge method. Likewise, it presents how the social, environmental and economic findings obtained through the PRA are analyzed and systematized so that they can be introduced into a model in systems dynamics by means of what has been called a "citizen factor".

Accordingly, the article is divided as follows: in the second section, the socioenvironmental and economic context of vereda El Pesebre, where the workshop took place, is shown; in the third section, it presents the development of the workshop, according to the methodology of the PRA, and also the results, the analysis and the systematization carried out concluding with the explanation of the obtained citizen factors; in the fourth section, the dynamic hypothesis is presented; after that, in the fifth section, it is exposed the system dynamics model; in the sixth section, the system of equations is detailed; in the seventh section the corresponding simulations and analyses are made; then, in the eighth section, an analysis of results is presented and contrasted against some previous related research; finally, the main research findings and future challenges for participatory modelling, system dynamics and their integration with other methodologies are detailed.

2. Context of vereda El Pesebre

Vereda El Pesebre is located south of the municipality of Tame in the department of Arauca in Colombia (Figure 1). It is surrounded by multiple natural resources and bioclimatic stages, thanks to the fact that part of its territory belongs to Nevado del Cocuy National Natural Park, where the main rivers, pipes and ravines that cross the region originate.

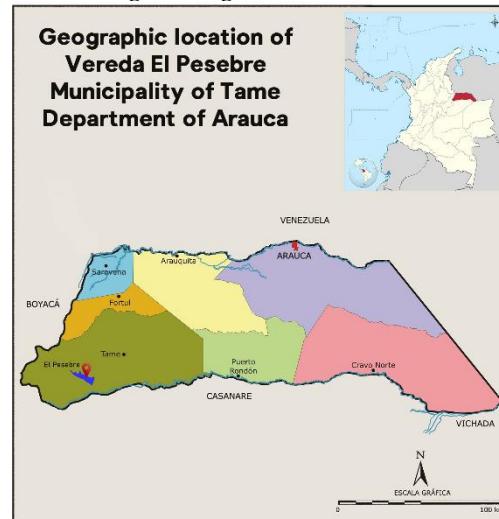


Figure 1. Geographic location of Vereda El Pesebre.

Source: Adapted from (Milenioscuro, 2012; SOGECOL, 2002)

In the social and economic sphere, vereda El Pesebre was not unrelated to the conflict in the region and throughout the country, situation that led this community, as well as many others, to a stagnation in social and economic development. This backwardness was most noticeable in rural areas and in communities that coincided with the strategic corridors for armed groups, where the war was most intense and often caused the displacement of their inhabitants.

It was in this way that in the community of El Pesebre the conflict led to productive activities, which not only constituted the sustenance of families, but were also an important part of the trade of the region, reduced to support for the minimum needs of its inhabitants. An important factor that slowed development even further was the forced displacement that occurred between 2007 and 2010, a period in which the territory was completely uninhabited and at the mercy of the armed groups that occupied the area.

3. Development of the participatory workshop

The working methodology proposed was the Participatory Rural Appraisal (PRA), from which it was prepared the workshop "Evaluating and Prioritizing our Resources", consisting of four sessions and three phases of work of diagnostic, evaluative and propositional type. These sessions and phases of work provided the necessary information to calibrate a sustainable social system that carries out the evaluation and prioritization of green projects in vereda El Pesebre in Tame, Arauca.

The focus was on the community and its natural resources, mainly water and land. Likewise, this methodology was chosen because it is multidisciplinary, flexible, open and collectivist, thus generating active participation, interaction and integration of knowledge, improvement of skills, attitudes and refinement of decision-making processes within the community that are useful for sustainable development in rural communities.

With regard to the development of the workshop, the diagnostic phase was implemented in the first session. The purpose of this phase was the recognition of the socio-economic, productive and environmental characteristics of the territory and it was possible by the development of collective tool building activities such as SWOT matrix methodology and Venn diagram, where environmental, socio-cultural, economic and productive issues were captured. In this session, the community was characterized by self-recognition. It was also possible for the facilitators to recognize these traits. Figure 2 shows the development of the diagnostic phase. At the end of the session, the technique of semi-structured dialogue with some of the participants was applied, which sought to address issues not addressed or in which there was not enough depth such as the history of vereda El Pesebre, the population and the different processes through which it passed and some others that continue to occur in the community and territory. The final conclusion of the session was summed up in the importance of the analysis of everyday life for the development and improvement of the quality of life in communities.

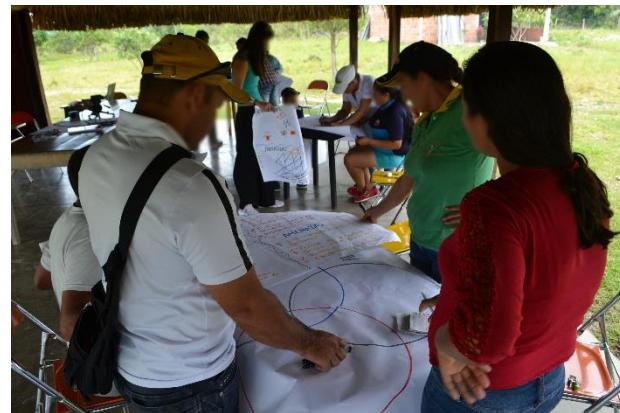


Figure 2. Development of the diagnostic phase.

Source: authors' own creation

The second session, which can be seen in Figure 3, consisted of a series of activities that sought a specific diagnosis around resources such as water and land. One of the activities carried out was the construction of a map of natural resources and land uses, which showed some of the characteristics of the territory and the community that inhabits it. This activity was complemented by a tour of the facilitators and some participants by the territory. Another activity was the seasonal calendar, in which the rainy and dry months were determined, and also the way they affect production, expenses, income, land and water sources, among others. Questions about basic resources in the household were also asked. Finally, the session ended with the elaboration of a diagram in which the different types of lands, their characteristics, their uses and their problems were specified. This diagram was made on the basis of previous activities, which facilitated its development.



Figure 3. Development of the evaluative phase.

Source: authors' own creation

In the third session, whose implementation is shown in Figure 4, the propositional phase was developed. The objective was for the community to assess the resources available in its territory, its quality, quantity, access and forms of use. Diagrama de cuenca, which sought to identify the natural resources available in the region, was proposed as a starting point, an initial activity for discussing environmental interactions in the community's area of influence. After socialization, based on the information collected, activities such as the resource assessment matrix were developed. This activity sought that the participants were the evaluators of resources such as water, land, pastures and crops, making their potentialities and weaknesses visible. The session ended with the development of questions related to access to resources.



Figure 4. Implementation of the propositional phase.

Source: authors' own creation

3.1. Outcomes of the participatory workshop

The Colombian Orinoquía, the region where vereda El Pesebre is located, has traditionally been associated with livestock and grazing activities. Although this has been its main source of economic development within the surrounding territories, this activity has been reduced due to the low quality of the lands, the initial investment required, support costs and their difficulty in transport and commercialization.

In contrast, in vereda El Pesebre there are other modes of production such as agriculture and livestock, which do not have sufficient support (economic and technical) to make these activities promote the integral development of the community. Agriculture bases its activity on the production of food such as cassava, bananas and some fruits, destined only for self-consumption. A special case is the cultivation of coffee that is in a period of strengthening and expansion within the families in the El Pesebre. Although coffee production is currently minimal and does not represent a development factor for the community, it is projected into the future as a source of growth thanks to the already existing national and international market [3].

On the other hand, the community is perceived with high rates of social cohesion and literacy. In addition, another positive aspect that is highlighted in the community is the absence of problems related to drugs (crops, sale and consumption). These qualities have allowed the community to have a healthy coexistence and enable environments for community entrepreneurship and associativity as is the case of the apiculture project that has been developed in recent years thanks the association Granja Integral Tamarindo (GRANITA) ties to Agencia Promotora de Desarrollo Económico Regional (APRODEL), that develops this and other United Nations Development Programme (UNDP) projects in the region.

Thus, the support provided by these institutions in the region has become an engine of economic development for the inhabitants. In the specific case of the apiculture project, it is observed that this activity has become one of the main sources of income for the inhabitants of vereda El Pesebre.

Although the community recognizes the water quality of its tributaries and identifies its main productive areas, from the savannah to livestock and beekeeping, through the buffer zone or the low mountain, up to the high mountain corresponding to Nevado del Cocuy National Natural Park, a protected and tourist area, the support they receive to undertake productive projects in any part of the territory is insufficient. Figure 5 shows the income perception of the inhabitants of vereda El Pesebre versus the use of the land destined for each productive activity.

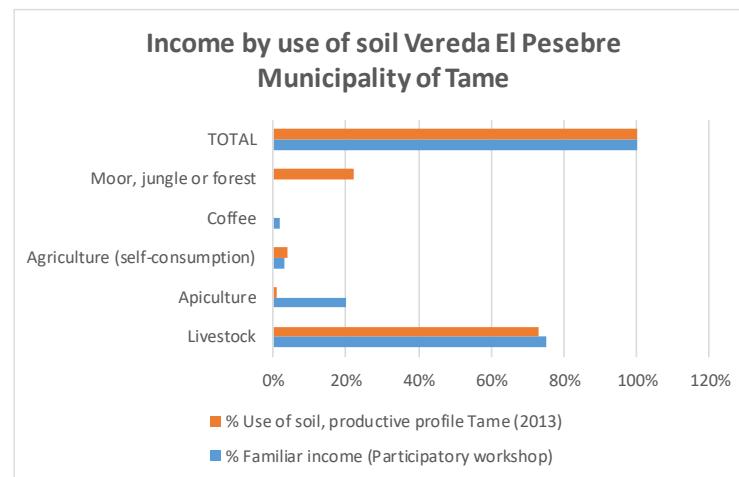


Figure 5. The income perception for land use

Source: authors' own creation

It can be observed that, although livestock is still the main mode of production, to obtain a profitability close to 30% per year it requires a high investment and a high consumption of land, water and time.

On the contrary, apiculture, an activity that is consolidating in the region, requires a considerably lower investment with respect to livestock, and the requirements for water and land use are minimal as are the demand for care. In addition, with this activity it is possible to reach profitability of nearly 40%.

Something similar happens with the cultivation of coffee that is newly incorporated into the productive activities of the territory. Although compared to apiculture requires more investment and greater use of land and water, this activity has the advantage of having a consolidated national market and that allows all production to be guaranteed sale. Other products such as cassava and banana, which could reach a production of up to 1200 kilos per hectare, are not easily marketed in the area, which is why they are destined for the consumption in El Pesebre. Although this type of crop does not require irrigation other than that given by the rainy season, the areas where they are produced are minimal.

Also, the participatory workshop allowed to identify that in vereda El Pesebre, the needs that the community considers urgent are related to the lack of social infrastructure, public services, health and technology. This situation, as expressed by the inhabitants of the village, is a direct consequence of the armed conflict in the region. It was also possible to highlight other effects of the conflict, such as isolation and social and economic discrimination. This is reflected over time in inequity, low quality of life and, in general, in the community being considered as a peripheral territory with few opportunities for development.

With regard to the expectations and the projection of the community, the participatory workshop made visible the environmental awareness of the inhabitants that was evident in their interest in the protection and reforestation of Nevado del Cocuy National Natural Park, as well as in the care of the rivers that are born there. This park is considered as the central axis that can bring development to the territory, that is why the community expresses its interest in activities aimed at creating environmental awareness and in green conservation projects that can be generated through rural and environmental tourism.

Similarly, the results of the workshop show the marked influence that the development of apiculture has had on the economy, to the extent that the community expresses its interest in initiatives that in the medium and long term will allow them to create a collection center that will facilitate product logistics activities and their expansion at the regional and national levels.

Even so, the community of vereda El Pesebre continues to see livestock as an important source of income in the future, but they also recognize the challenges that must be faced with regard to processes of technification and reduction of environmental impact, so that this activity can generate greater income for the population.

With regard to the coverage and quality of services and public infrastructures such as aqueduct, sewage, garbage collection, sports centers, educational institutions (elementary and high schools) and health posts, the community is excited to manage the necessary projects with local authorities. Likewise, they express their interest in achieving external alliances that allow them to train the community around productive activities and that promote organized work, the sense of belonging and receptivity in its inhabitants.

In conclusion, the inhabitants of vereda El Pesebre highlighted that the activities carried out in the participatory workshop allowed to strengthen the unity of the community, recognize the strengths as a group and also the wealth in natural resources. Likewise, failures, bad practices and aspects to improve were identified that can be transformed into productive projects or progress in the quality of life of their inhabitants.

This was made possible by the fact that the PRA methodology, applied in all the sessions of the workshop, created bonds of trust with the facilitator team, which allowed to deepen the knowledge of the community while generating relevant information and social learning. Although not all the community attended the workshops, a participation of about 20% was obtained, which showed the interest in the topics treated and, in general, for the future that awaits this community.

3.2. Citizen Factor

The participatory workshop developed with the community in vereda El Pesebre allowed to find and prioritize both the problems and the needs and expectations that arise at the social, economic and environmental levels. This, in turn, allowed the facilitator team to establish two citizen factors, that is, components that have a marked influence on the projects and initiatives that are carried out in the area, and that can also be expressed mathematically in the form of a percentage. These factors are the citizen factor water (CFwater) and the citizen factor land (CFland). According to these two factors, it is possible to determine what type of projects the community needs, prefers or expects depending on its current situation and, in addition, to express it as a percentage amount that will affect in one way or another the results of the proposed model.

Then, for each of the factors, CFwater and CFland, the facilitator team sought to establish, according to the results of the participatory workshop, the importance in percentage terms of those types of projects that may have greater relevance in the community. In this sense, three subcategories were defined for each citizen factor: the social sub-factor, the environmental sub-factor and the economic sub-factor.

With respect to vereda El Pesebre, there were great differences between the defined citizen factors. On the one hand, although both resources are abundant in the area, the water is used in a better way and also represents greater importance for the inhabitants; on the other hand, the land resource has not only been wasted, but also underused, due to lack of knowledge and lack of technical and financial support to start projects that directly involve them, such as agricultural projects.

Nevertheless, it is also recognized that the main economic activity of the population, livestock, is thanks to the large areas of land they have. Therefore, for the purposes of this research, it was decided to give the following values to the citizen factors of water according to the opinions and results of the participatory workshop:

Env CFwater: 25%

Soc CFwater: 30%

Eco CFwater: 45%

And to the citizen factors of land, like this:

Env CFsoil: 20%

Soc CFsoil: 30%

Eco CFsoil: 50%

In addition, it was found that the economic factor is the most prevalent for the inhabitants of vereda El Pesebre. In this sense, development, consolidation and expansion of apiculture activities and the support of livestock are the actions that currently play a very important role for the local economy. Table 1 summarizes and defines the parameters by which the citizen factor was determined.

Citizen Factors	Description	Value	Units
IEn Water	Importance of water-based environmental development versus economic and social development, indicated by the community	25	%
IEnP Water	Importance of the development of Environmental Projects with a focus on water versus other types of projects (social, economic), indicated by the community	25	%
IS Water	Importance of water-based social development versus environmental and economic development, indicated by the community	30	%
ISP Water	Importance of the development of Social Projects with a focus on water versus other types of projects (environmental, economic), indicated by the community	30	%

IEc Water	Importance of water-based economic development versus social or environmental development, indicated by the community	45	%
IEcP Water	Importance of the development of Economic Projects with a focus on water versus other types of projects (environmental, social), indicated by the community	45	%
IEn Land	Importance of land-based environmental development versus economic and social development, indicated by the community	20	%
IEnP Land	Importance of the development of Environmental Projects with a focus on land versus other types of projects (social, economic), indicated by the community	20	%
IS Land	Importance of land-based social development versus environmental and economic development, indicated by the community	30	%
ISP Land	Importance of the development of Social Projects with a focus on land versus other types of projects (environmental, economic), indicated by the community	30	%
IEc Land	Importance of land-based economic development versus social or environmental development, indicated by the community	50	%
IEcP Land	Importance of the development of Economic Projects with a focus on land versus other types of projects (environmental, social), indicated by the community	50	%

Table 1. Citizen factors determined through the participatory workshop.

4. Dynamic hypothesis

This research was based on the model defined by Castrillón-Gómez, Valencia-Calvo and Olivari-Tost [4]. This system uses the principles of supply and demand set out in Dyner [5], but now applied to the design of a sustainable development structure, in which two main attributes are used as bridges between the other attributes that complete the system; the first is determined by the relationship between supply and demand for water and the second is determined by the relationship between supply and demand for land.

In the same order, bridges refer to the reserve margins of water and land, and these reserve margins refer to the availability of each existing resource according to its use and they were used as the elements that allowed the interaction between the incentives for green projects and the investment that could be made available by local government for implementation of community initiatives.

According to Figure 6, the main hypothesis for the construction of the model is the impact of investment decisions and incentives for investment in green projects, depending on the availability of natural resources of water and land and the citizen factor established through the participatory workshop previously conducted with the community.

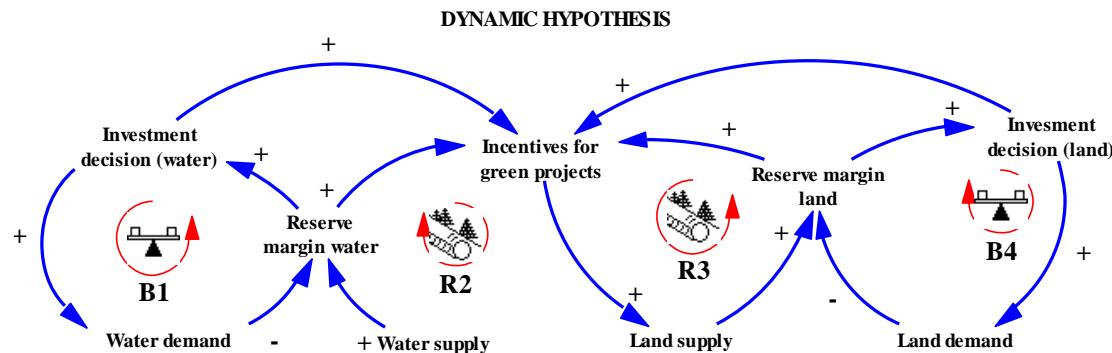


Figure 6. Dynamic hypothesis
Source: Extract from Castrillón-Gómez, Valencia Calvo y Olivar-Tost [4]

While it is useful to build a reserve margin to monitor the current state of resources, it is also important to determine the degree of influence, represented by the citizen factor, that the community has over the prioritization of green projects, in such a way that it is not only possible to intervene in order to achieve a balance between the use and harnessing of resources, but also in accordance with the problems, needs or expectations of the inhabitants.

As for the balance cycles B1 and B4 shown in Figure 6, these correspond to the water demand and the land demand, respectively. Now, the R2 and R3 reinforcement cycles, which are responsible for stabilizing the use of resources thanks to their snowball effect, are also affected by the defined citizen factors, causing the prioritization to shift proportionally towards the type of projects the community would expect to obtain. Through this approach, depending on water and land reserve margins and citizen factors, new investments will be made in green projects. Just as negative reserve margins may indicate scarcity in one resource or another, citizen factors will indicate where to prioritize investments when this occurs, information that may be key to rethinking the type of projects to be developed in the community and, in some way, increase their chances of success.

On the other hand, when reserve margins are positive, a balance in the use of resources or their abundance is evident. In this case, although the citizen factor is not evident within the model, it is useful for decision-making because it provides information regarding the needs or expectations of the community, which allows to raise and develop the best initiatives. It should be noted that this research is focused on prioritizing projects in areas where water or land resources may be in short supply at some point.

5. Simulation model

The flow and level diagram presented in Figure 7 corresponds to an adaptation of the work carried out by Castrillón-Gómez, Valencia-Calvo y Olivar-Tost. This diagram shows the variables of the proposed model, including for this research an additional state variable corresponding to the population. The dynamic hypothesis shown above is now detailed in a Forrester simulation model, in which two state variables, represented by rectangles, are considered. The others, considered as auxiliary variables, are symbolized with circles. The connections between the different variables represent the information flows, through which the flow of material in the state variables is controlled.

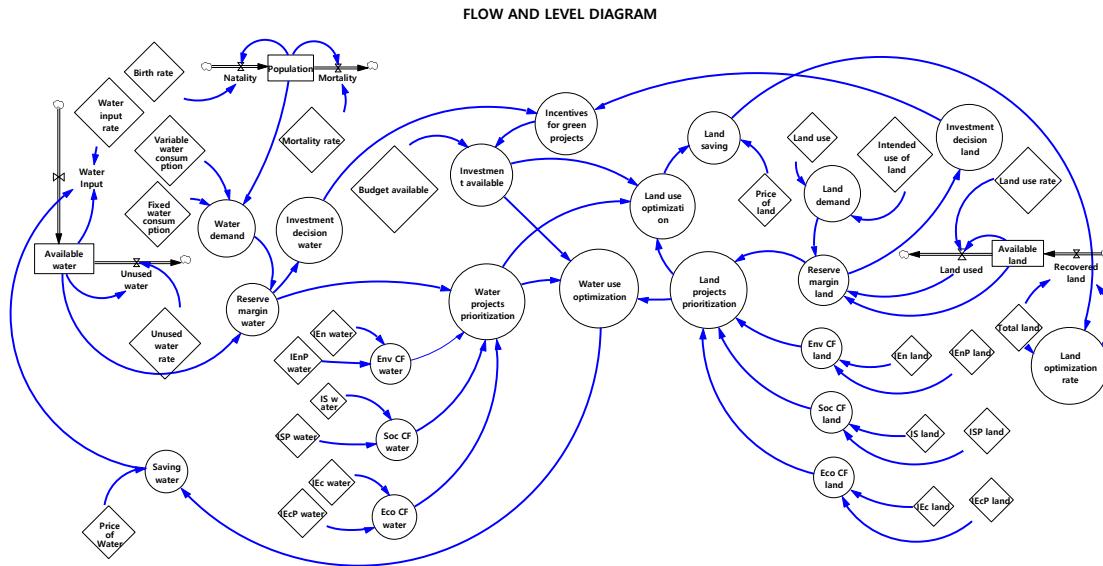


Figure 7. Flow and level diagram

Source: adapted from Castrillón Gómez, Valencia Calvo y Olivar-Tost [4]

From the diagram we have that the incentives to green projects are modeled as a piecewise function, in which the investments depend on the decision of investment water and the decision of investment land, while the variables of optimization of water use and optimization of land use, respond not only to the financial factor (or available investment), but also to the prioritization of projects, understood as citizen factors (environmental, social and economic) described above and already defined with the community through the development of participatory workshops. Thus, it was possible to tune the model in such a way that the context, needs and expectations of the community will be reflected in the system quantitatively, situation that is usually not considered within government schemes or centralized institutional representation. The investment decisions in water and land refer to the availability of these natural resources, in this case, in the community of vereda El Pesebre. Therefore, these variables, together with the citizen factors, are the ones that affect in greater or lesser proportion the model and, consequently, the decision-making in relation to the green projects that are planned to develop in the area.

6. System of equations

The flow and level diagram presented in Figure 7 is also a mathematical object and it is possible to write it as a system of differential equations that represent the supply and demand of the natural resources of water and land as motivators for investments in green projects.

$$\begin{aligned} \dot{r}_1 &= -ar_1 + W \\ \dot{r}_2 &= -br_2 + L \end{aligned} \quad (1)$$

In Equation (1), r_1 corresponds to the available water resource; r_2 corresponds to the available land resource; a corresponds to the index of unaccounted-for water; and b corresponds to the rate of land use. In the case of the municipality of Tame, part of which is vereda El Pesebre, the index of unaccounted-for water is estimated at 31.68%, according to data obtained from the management report of aqueduct, waste management and sewage company of the region [6]. As for the rate of land use, it is estimated at 1.17%, calculated according to the information given in the production profile of the municipality of Tame [7].

In relation to the water contributions defined as W , vereda El Pesebre has Lopeño and Lejía rivers as main tributaries. Because the municipality does not have limnometric stations in any of the rivers, it is not possible to have an updated measure of its flows. However, taking into account that Lopeño River is ranked in the order of five (by its number of tributaries), just after the Tame River,

classified in order four, this model will be assuming the estimated flow rate of the river Tame, which is 23.96m³ on average. On the other hand, another major water supply in the region is given by annual rainfall levels, which have an average of 2890 mm per year. W , as shown in equation (2), besides being defined as a continuous function, depends on the saving of this natural resource (S_{water}) depending upon the price per cubic meter ($Price_{water}$), which, for this region, is valued at approximately 6000 Colombian pesos per m³ in rural areas. L is the amount of land that can be optimized for the development of sustainable projects which, for the particular case of the municipality of Tame, corresponds to the number of hectares in the process of technification, 3933 approximately [7]. L , as shown in equation (3), is also a continuous function that depends on the savings achieved in this natural resource, expressed as (S_{soil}) depending upon the price per hectare, which, for the case of the department of Arauca (where vereda El Pesebre is located), has an average value of 150.000 Colombian pesos [9].

$$S_{water} = \frac{O_{water}}{Price_{water}} \quad (2)$$

$$S_{soil} = \frac{O_{soil}}{Price_{soil}} \quad (3)$$

Now, land use optimization (O_{soil}) and water use optimization (O_{water}), equations (4) and (5), are defined as the percentages by which the available investment is divided (I), as follows:

$$O_{soil} = \left(1 - \frac{P_s}{P_w + P_s}\right) * I \quad (4)$$

$$O_{water} = \left(1 - \frac{P_w}{P_w + P_s}\right) * I \quad (5)$$

Where, P_w corresponds to the Water Project Prioritization and is defined as a step function that depends on the water reserve margin (RM_w) and the citizen factor found through community participation, which can be social (CF_s), environmental (CF_{en}) and economic (CF_{ec}). Likewise, P_s corresponds to the Land Projects Prioritization and is defined as a step function that depends on the land reserve margin (RM_s) and the citizen factor found through community participation already defined above: (CF_s), (CF_{en}) and (CF_{ec}).

With respect to reserve margins, (RM_w) and (RM_s), they measure the relationship between water supply and demand and land supply and demand, respectively. Therefore, Water Project Prioritization (P_w) and Land Projects Prioritization (P_s), are defined as shown below in the equations (6) and (7).

$$P_w = \begin{cases} RM_w * CF_s, & RM_w < 0.1 \\ RM_w * (CF_s + CF_{en}), & 0.1 < RM_w < 0.6 \\ RM_w * (CF_s + CF_{en} + CF_{ec}), & RM_w > 0.6 \end{cases} \quad (6)$$

$$P_s = \begin{cases} RM_s * CF_s, & RM_s < 0.1 \\ RM_s * (CF_s + CF_{en}), & 0.1 < RM_s < 0.6 \\ RM_s * (CF_s + CF_{en} + CF_{ec}), & RM_s > 0.6 \end{cases} \quad (7)$$

The available investment remains to be defined, which corresponds to the relationship between the budget available for investment in projects and incentives for green projects. For the proposed model, the Available Investment Variable (I) will have an initial value of fifty million pesos and will be varied to obtain different analysis scenarios. On the other hand, the incentives to green projects I_p are defined as the stimuli to the initiatives in sustainable development and, in this case, corresponds to the average between the decision of investment in water and the decision of investment in land (D_{water} D_{soil}) multiplied by investment I . Investment decisions are step functions that depend on their respective reserve margins and are shown in equations (8) and (9).

$$D_{water} = \begin{cases} 1, & RM_w < 0.1 \\ 0.6, & 0.1 < RM_w < 0.6 \\ 0.1, & RM_w > 0.6 \end{cases} \quad (8)$$

$$D_{water} = \begin{cases} 1, RM_s < 0.1 \\ 0.6, 0.1 < RM_s < 0.6 \\ 0.1, RM_s > 0.6 \end{cases} \quad (9)$$

The table 2 below shows the parameters used during the simulations, their description, the units of measurement of each of them and the source from which they were obtained. It is important to note that the budget available for investment may change, but for this research an average value of 50 million pesos is assumed. This amount is adjustable according to the financial circumstances established by each municipality.

Parameter	Description	Value	Units	Source
Water Input	Amount of water provided by the different tributaries in the area per year	22	%	[8]
Unused Water Rate	Amount of water not consumed or used per year	45	%	[6]
Variable Consumption of Water	Amount of water consumed above annual average	60	Cubic meters	[6]
Fixed consumption of water	Amount of water consumed per year	130	Cubic meters	[6]
Population	Number of inhabitants	50	people	[7]
Price of Water	Value paid per m ³ of water	6000	Pesos	[6]
Available budget	Amount of money available for investment	50	Million pesos	[9]
Price of Land	Average value paid per hectare of land	150	Thousands pesos	[9]
Land Use	Amount of land consumed per year	9000	hectares	[9]
Intended use of land	Proportion of land (to total) planned to be used for the following years	30	%	[7]
Land Use Rate	Proportion of land (to total) used each year	15	%	[7]
Total Land	Total hectares of land (used and unused)	515	thousands of hectares	[7]

Table 2. Parameters used for model simulation.

7. Simulations and analyses

The following simulations confirm the hypothesis that was raised from the beginning. On the one hand, the balance cycles B1 and B4 of Figure 8 show how the change in the levels of supply and demand of water or land, represented in the defined margins, generate key information, by way of alerts, which allow for proper monitoring of investments.

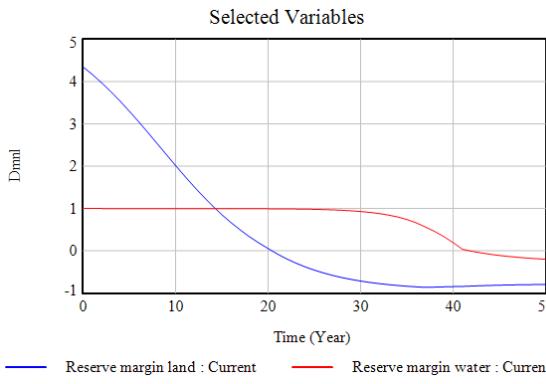


Figure 8. Changes in water and land supply and demand levels

On the other hand, it is observed how the reinforcement cycle (R1) is influenced by the citizen factors that were established through community participation. According to Figure 9, it is evident how the community of the vereda El Pesebre gives preference to projects related to water, that is, those in which its water sources can be used for an economic purpose for its inhabitants.

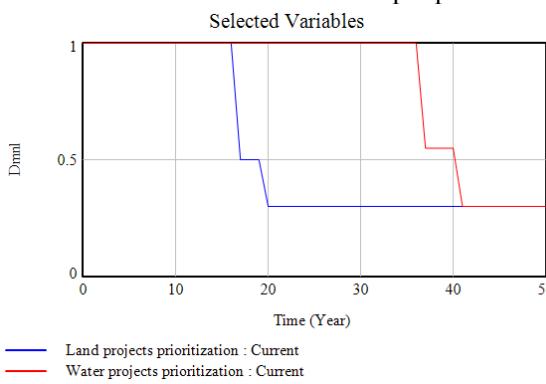


Figure 9. Prioritization of projects according to the citizen factor

However, despite this strong interest, the current reality shows that the land projects are the privileged ones. This situation is not associated with a factor of reduction or scarcity of water, but is directly related to financial support to development of projects related to land use. Thus, the interest that apiculture and livestock projects have aroused in the community is hardly normal, since large areas of land can be used with minimal investment. In addition, such projects are, in part, sponsored by the local government and some cooperatives in the region.

Now, Figure 10 and Figure 11 show how investment decisions are, to some extent, influenced by the citizen factor that represents local knowledge in relation to the needs and expectations of the community. This can give clear light to decision-makers, perhaps not to choose the projects acceptable to government or institutions at the financial or political level, but the ones most suitable for the community. In the case of vereda El Pesebre, the fact that the citizen factor had given priority to water and social projects, highlights, in the first place, its lack of sanitary infrastructure, aqueduct and sewerage, drinking water and solid waste disposal; and, secondly, its willingness to undertake economic - environmental projects, such as eco-tourism, in which water sources and the Nevado del Cocuy National Natural Park are the main attractions.

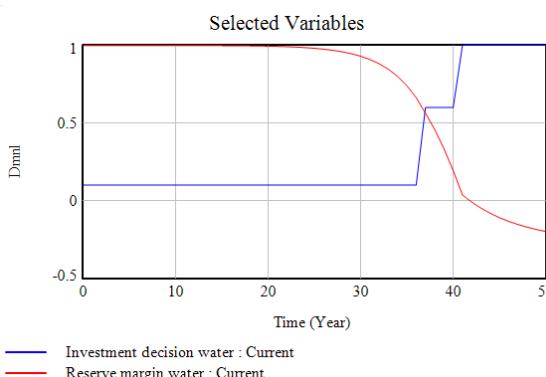
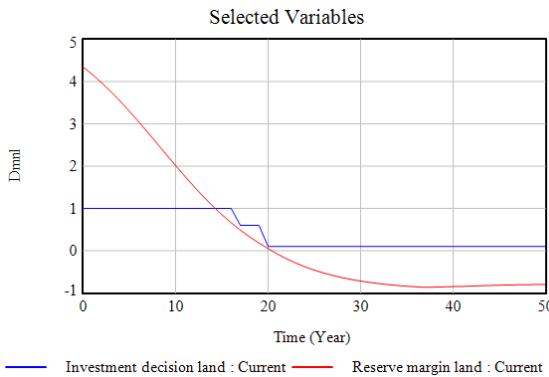
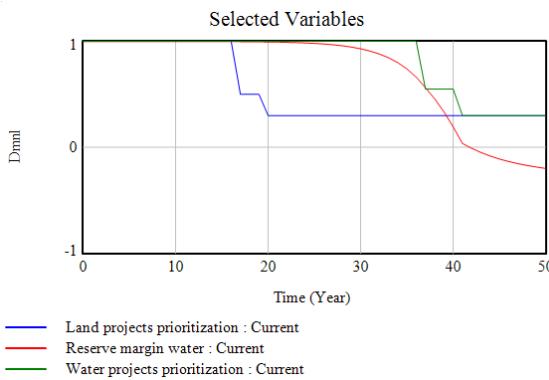
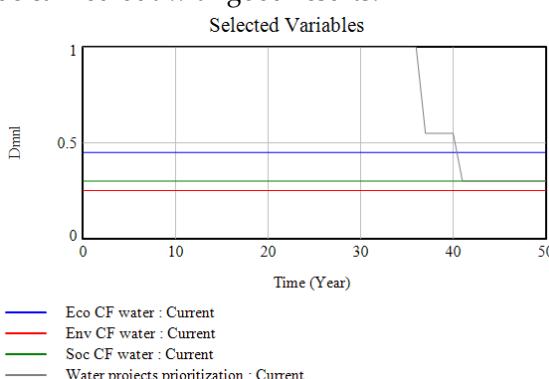


Figure 10. Influence of citizen factors on investment decisions (water)**Figure 11.** Influence of citizen factors on investment decisions (land)

Although reserve margins provide decision-makers with an overview of the projects that can be carried out in the area and, in addition, allow taking stock of resources to avoid shortages, it is observed that local knowledge acts in crisis situations. Thus, for example, Figure 12 shows that in the face of a possible shortage of water, the citizen factor prioritizes the initiatives that impact water to strengthen those economic activities that require it, maintaining the standard of living of its inhabitants.

**Figure 12.** Response of the citizen factor to possible scarcity of resources

And, although it can be said vereda El Pesebre has a notorious abundance of water and land resources, which makes the reserve margins are positive even during the summer season (information obtained from the activity carried out in the participatory workshop, called the seasonal calendar), again the citizen factor inclines the decision-making, in this case, as shown in Figure 13 and Figure 14, towards economic projects that influence the improvement of the quality of life of the population. At this point, it is the expectations of the population that are expressed in the model, since, as mentioned above, since there is a positive reserve margin for both variables, any project (in water or land) is feasible to be carried out with good results.

**Figure 13.** Preference for water-related projects favoring the region's economy

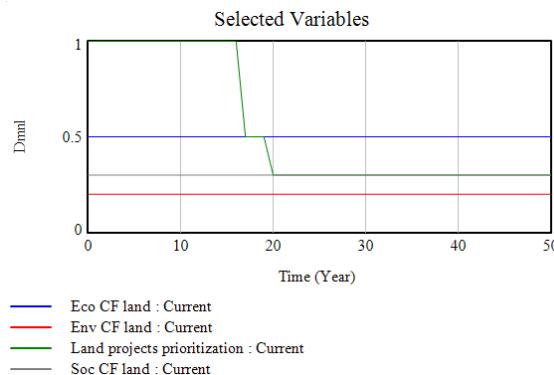


Figure 14. Preference for land-related projects favoring the region's economy

8. Preliminary discussion

Decision-making in the evaluation and prioritization of green projects rarely focuses on the availability of natural resources and the citizen factor of the place where the initiatives will be carried out, as key elements that could not only help in the control and protection of the environment, but also in the management of investments and incentives for the selection of projects to be implemented in an appropriate manner and to be successful in meeting, as expressed by Reed [11], the needs and perhaps even the expectations of a community.

Also, because project decisions must be adjusted to the available investment resources, it is necessary to take extra care in the selection. In addition to assessing the quality of the proposals or the results obtained in other communities, significant environmental and economic aspects of the locality will also be taken into account, as well as the social conditions that, as mentioned in Johnson et al. [12], to some extent, can determine the success or failure of a project.

An approximation to the above problem is made in Castrillon-Gomez, Valencia-Calvo y Olivar-Tost [4], where the dynamics of systems is an appropriate tool to achieve the objective of representing part of the social, environmental and economic dynamics of a community and, at the same time, integrating quantitative variables, such as the investment and reserve margins of natural resources, and also qualitative variables, such as the needs and expectations of the community reflected by the citizen factor.

However, as mentioned in Castrillón-Gomez, Orozco-Orozco, Valencia-Calvo and Olivar-Tost [3], the concept of qualitative in the evaluation and prioritization of projects has different connotations when it comes to sustainable development and, in a post-conflict context such as the one currently living in vereda El Pesebre and many other communities in Colombia, it would also be expected to break with the homogenization of initiatives and particular interests in order to achieve a relevant integration between community, research (academia) and decision-making (project selection).

Therefore, there is still a need to link various valuation methods in order to achieve a systemic assessment. At this point, the system dynamics through which, as expressed in Forrester [13], it is possible to adequately represent a part of reality, is presented, in the first place, as an alternative to answer the problem under investigation. Studies such as those presented in Davies & Simonovic [14], Ahmad & Simonovic [15] and Azmi & Sarmadi [16] succeed in modelling sustainable development systems by exploring some main axes such as production, population, water and land use, climate and ecological footprint, among others, using methodologies such as system dynamics and participatory modelling.

Second, the dynamical systems defined in Aracil & Gordillo [17] and subsequently in Sterman [18], as the set of equations through which model behaviors are simulated and analyzed, are increasingly used and their usefulness is highlighted in decision-making based on constructed analyses and simulations. Some research that shows its scope has been used, for example, to estimate the ecological footprint, the water footprint, and also to determine the supply and demand of water and land.

Regarding the use of participation and social learning tools presented in the research of authors such as Tàbara & Pahl-Wost [21], Pahl-Wostl [22] and Little, Hester, & Carey [23], among others, allow to carry out different types of analysis or diagnoses that can be experimental, participatory or statistical. The choice of one of these tools will depend not only on the community, but also on the needs, time, and resources available.

However, the limitations that were presented due to the lack of technical information on planning and projects of the village El Pesebre, made it necessary to use the existing statistical data of the municipality of Tame (some of the year 2013) and also assumptions as to the available budget and incentives for green projects, in order to complete the calibration of the proposed model.

With regard to the validation of both, the system dynamics model and the dynamic systems model, the expert approach was used, looking essentially for logical consistency between the numerical results and the graphs obtained in addition to the dimensional consistency in the units and the results obtained in the equations. Finally, appropriate adjustments were made to the parameters by comparing the results with reality.

Consequently, the methodology presented in this research seeks to become a contribution to decision-making in the evaluation and prioritization of green projects, by integrating various methods so that consideration of proposals is not limited to the completion of bureaucratic formalities, but extends to consideration of the reserve margins of natural resources and knowledge of the needs and expectations of the community involved.

9. Conclusions

As a result of this research it was possible to show the different qualities of the community of vereda El Pesebre and the various factors to which it is exposed. Likewise, the diagnosis made allowed to know, not only the problems and needs of the community, but also the way in which they are associated to their geographic location and, consequently, to the availability of natural resources in the region.

On the other hand, it is noted that the use of the citizen factor integrated into a "generalist" model in which it is possible to adjust certain environmental, social and economic characteristics of a particular population, can generate relevant information within the same community that allows the creation, development and self-management of projects as well as the resolution of some local problems, thus building a comprehensive community development that improves the quality of life of its inhabitants.

Likewise, the research demonstrates how through the use of a set of mathematical, qualitative and citizen participation tools, it is possible to model the supply and demand of the natural resources of land and water. Based on this, it is possible to support decision-making regarding the evaluation and prioritization of green projects that are planned to develop in the short, medium and long term. In addition, it allows the generation of public policies for the control of water and land resources and the solution or mitigation of existing problems.

With respect to social participation, it is possible to show that the integration of local values and knowledge in the proposed sustainable development model achieves benefits and improves the quality of life of the community. This is because it increases social learning capabilities, as well as self-recognition, self-assessment and solution proposals.

Finally, it should be noted that the introduction of the citizen factor into a system dynamics model and the application of the concepts of supply and demand for natural resources is not a common practice when it comes to the evaluation and prioritization of green projects. Hence, their impact can be expanded and be decisive not only in improving investment decisions but also in increasing social learning and community empowerment.

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